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Operation Manual for Automatic Dichotomous Samplers, Application to Beckman Dichotomous Samplers

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Boston, MA

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Operation, calibration and maintenance procedures for the Beckman Automatic dichotomous sampler are described. This sampler is one of several currently available that simultaneously collect coarse and fine airborne particles.

The manual is intended for use by technicians and operators. It presents discussions of the nature of atmospheric particles and the basic operating principles as a means of providing operators with a more complete understanding of the instrument and its use.

Factors to be considered in site selection are discussed, followed by instructions for installation and checkout once the most suitable site has been identified. Special attention is given to checking for leaks in the flow system, as field experience has shown this to be a potential problem. Other areas of concern, such as operating instructions, calibration techniques, maintenance schedules, quality assurance, and trouble shooting are also addressed. The manual should serve as an effective supplement to information given in the manufacturer's instruction manual.

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Application to Beckman Dichotomous Samplers

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ABSTRACT

The Beckman automatic dichotomous sampler is one of several samplers currently available that simultaneously collects coarse and fine atmospheric particles. These instruments are becoming more widely used to support research and regulatory studies that require information on size fractionated particles. The operating manual is intended for use by technicians and operators of the Beckman sampler. It presents discussions of the nature of atmospheric particles and the basic operating principles as a means of providing operators with a more complete understanding of the instrument and its uses.

Factors to be considered in site selection are discussed, followed by instructions for installation and checkout once the most suitable site has been identified. Special attention is given to checking for leaks in the flow system, as field experience has shown this to be a potential problem. Other areas of concern such as operating instructions, calibration techniques, maintenance schedules, quality assurance, and trouble shooting are also addressed.

The manual should serve as an effective supplement to information given in the manufacturer's instruction manual. Various modifications to original equipment and instructions that will simplify and improve performance are described, including lists of parts and suggested suppliers. Areas of uncertainty about the design or performance are identified. The manual will be revised and updated as further field experience and research results become available.

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The authors wish to express their appreciation to Beckman Instruments Incorporated for permission to use printed materials from their instruction manual.

SECTION 1

INTRODUCTION

NATURE OF ATMOSPHERIC PARTICLES

This report describes the operation, calibration, and maintenance of the Beckman Automatic Dichotomous Sampler. This is one of several dichotomous samplers available, all of which are designed to collect simultaneously coarse and fine atmospheric particulates. Both coarse and fine particles are of special interest because the bimodal distribution of particles in the atmosphere reflects differences in sources (see Figure 1). In general, grinding, abrasion, and mechanical crushing produce particles in the coarse mode approximately 2.5 μm in diameter and larger. Particles in the accumulation of fine size range are in general formed from combustion either directly or by gas to aerosol conversion. These fine sized particles are believed to be of greater concern for health effects because they will more readily penetrate to the deeper portions of the lungs.

Because of the differences in mechanisms of formation, fine and coarse particles generally have distinctly different chemical compositions. Many of the elements found in the soil, such as silicon, calcium, iron, and aluminum, generally appear in the coarse particle mode. Products of combustion activity such as sulfates, nitrates, organics, lead and soot are generally found in the fine particle fraction.

Once suspended in the atmosphere particles are subject to gravitational, diffusional and other forces as well as cloud forming processes that continually modify their distribution. As a result, the ultra fine particles are agglomerating and growing in size, thus adding to the fine particles in the accumulation mode from .1 to 2.5 μm in diameter. Gravitational settling

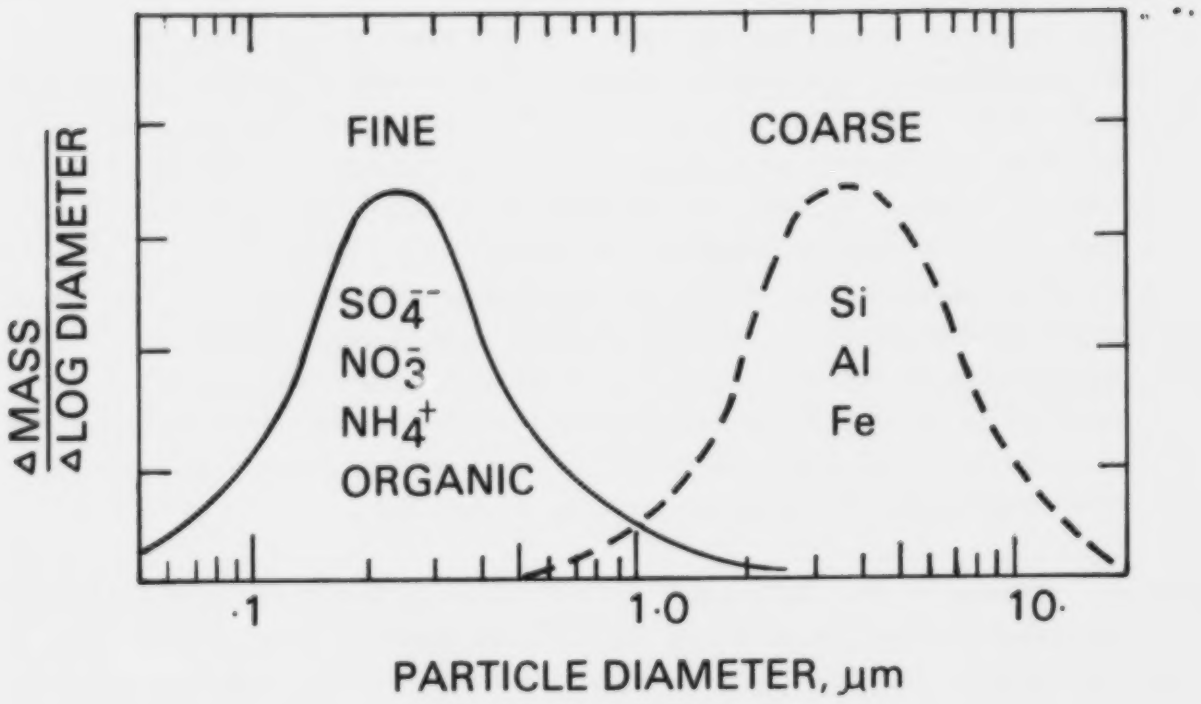

Figure 1. Size distribution and chemical composition of fine and coarse atmospheric particles (1)

and inertial impaction act on larger particles to remove them from the atmosphere. Although at times there will be particles as large as 50 μm to 100 μm suspended in the lower atmosphere, the mass of these coarse fraction particles is distributed around 10 μm in diameter. The dichotomous sampler was specifically designed to collect suspended particulate matter separately in both the fine and coarse size ranges. This is consistent with particle size distributions in the atmosphere and the retention of particles in the upper and lower human respiratory tract.

Since the dichotomous sampler collects the fine and coarse particles on separate filters, these filters can be used in subsequent analysis. Techniques such as x-ray fluorescence (XRF) provide information on approximately 20 elements. Ion chromatography can identify sulfate, nitrate, and ammonium ions, among others. This information is valuable in identifying source contributions to ambient concentrations and the toxicity due to specific metals or compounds. Sampling of the fine and coarse fraction may aid the assessment of visibility reduction problems and fugitive dusts.

DESCRIPTION OF THE INSTRUMENT

This report describes the operation and calibration of the Beckman Automated Dichotomous Particulate Sampling System, hereafter referred to as the dichotomous sampler or the Beckman sampler. All components except for the inlet are housed in a weather resistant, internally heated enclosure, shown in Figure 2. Air is drawn into the instrument through the fractionating inlet, which is designed so that particles larger than approximately 15 μm are excluded. The air sample next flows through a virtual impactor, which simultaneously separates the particles into a fine fraction and coarse fraction. The two size fractions are then deposited on separate filters for subsequent analysis. Air flow through the sampler is maintained by separate fine and coarse flow systems.

An important feature of the Beckman dichotomous sampler is its microprocessor control system, which allows for automated continuous sampling. Two filter trays, each containing 36 filters, are placed in the sample changer

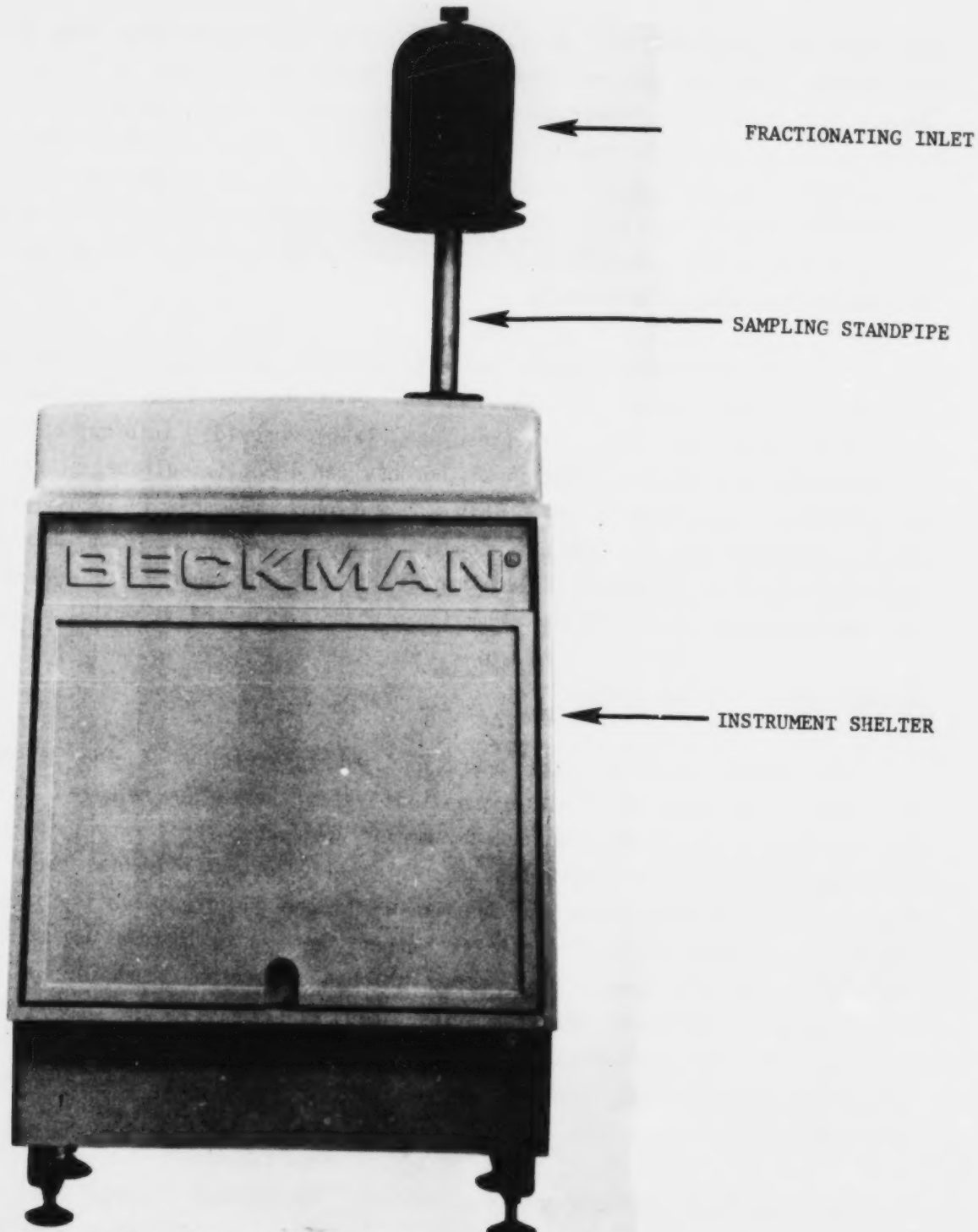

Figure 2. Beckman Automated Dichotomous Sampler, Showing Housing, Standpipe, and Fractionating Inlet in Operating Position

(see Figure 7). The sampler can then be programmed to collect automatically 35 pairs of samples, at preselected times and sampling intervals. (One pair of filters is always maintained unexposed as a control.) A heater/thermostat system maintains the internal temperature at 33°C and permits sampling through variations in ambient temperatures of -40°C to +50°C.

A more detailed discussion of instrument subsystems and operating principles is provided in Section 2 of this report. Instrument specifications are given below.

PURPOSE AND USE OF DOCUMENT

This report is primarily for use by those responsibile for establishing and operating dichotomous sampler networks and for field personnel responsible for maintenance and calibration of the Beckman sampler. The report is designed to provide background information and descriptions of how the sampler works and suggestions for its use. Considerations for site selection are provided along with installation instructions. Calibration, operation and maintenance procedures are presented, along with suggested quality assurance and data handling procedures. The information is based on materials provided by the manufacturer along with the results of extensive field use of the instrument. It is expected that the manufacturer's instruction manual (2), including trouble shooting procedures and instrument schematics diagrams, will be available to the user of this report.

SPECIFICATIONS

Inlet Upper Cutoff Point (50%):	15 μm nominal; 12 to 18 μm for wind speeds below 20 km/hr
Virtual Impactor Cut Point (50%):	2.5 μm
Virtual Impactor Losses:	<5% for particles between 1 and 15 μm aerodynamic diameter; <15% at cut point
Sample Flow Rate:	16.7 ℓ/min total (1 cubic meter per hr)

Sample Flow Stability:	±5% per week
Timing Accuracy:	±2 min per day
Start Time Selction:	Presettable to any number of days, hours, or minutes up to 365, 23, and 59, respectively
Delay Period Between Samples or Sample Groups:	Presettable to any number of days, hours or minutes up to 364, 23, 59
Number of Filters per Group:	Presettable from 1 to 36 filters
Filter Material:	1 µm Teflon standard, 2 µm optional
Filter Size:	29 µm deposit dia. on 5 cm x 5 cm square frame
Number of Filters:	36 pair in 2 trays
Housing:	Weathertight; internally temperature controlled at 33°C
Ambient Operating Temperature Range:	-40° to +122°F (-40° to +50°C)
Operating Humidity Range:	0 to 100% RH
Power Required:	115 VAC, 60 Hz; 200 VA nominal at 25°C with pumps off; 300 VA max at 25°C with pumps on; 850 VA max with heaters and pumps on
Power Failure:	Battery pack maintains timekeeping function for 30 min should power fail; time of power failure is printed
Power Cord:	8 ft (2.4 m) long, U-ground plug
Dimensions:	40 in. H x 26 in. W x 19½ in. D (102 x 66 x 50 cm); plus inlet protrudes 20 in. (51 cm) from top
Instrument Weight:	175 lb (80 kg)
Shipping Weight:	220 lb (100 kg)

SECTION 2

PRINCIPLES OF OPERATION

This section gives an explanation of the principles of operation for the six main components of the dichotomous sampler: fractionating inlet, virtual impactor, sample flow system, filter system, temperature control system and sampler control system. Figure 3 shows the major subassemblies which are readily visible with the front cover removed.

SAMPLER INLET

The air sample enters the fractionating inlet, which protrudes from the top of the sampler housing as shown in Figure 2. Because the bell shaped inlet has axial symmetry, the sampling efficiency is independent of wind direction. With air entering through the bottom of the inlet, rain is kept out, and a coarse screen keeps large particles and insects from being entrained. The inlet is designed so that particles greater than 30 μm will not enter. Particles between about 15 μm and 30 μm have a settling velocity roughly equivalent to the average upward velocity of the inlet so that these particles settle out of the inlet and do not enter the impactor (3); thus the inlet 50% cutpoint is 15 μm, i.e., the inlet is approximately 50 % efficient at collecting 15 μm particles. It should be noted that wind speed does affect the inlet performance. Efforts are underway to study the effect of wind speed on size cutoff, and operators should check latest information on wind speed dependence and inlet design.

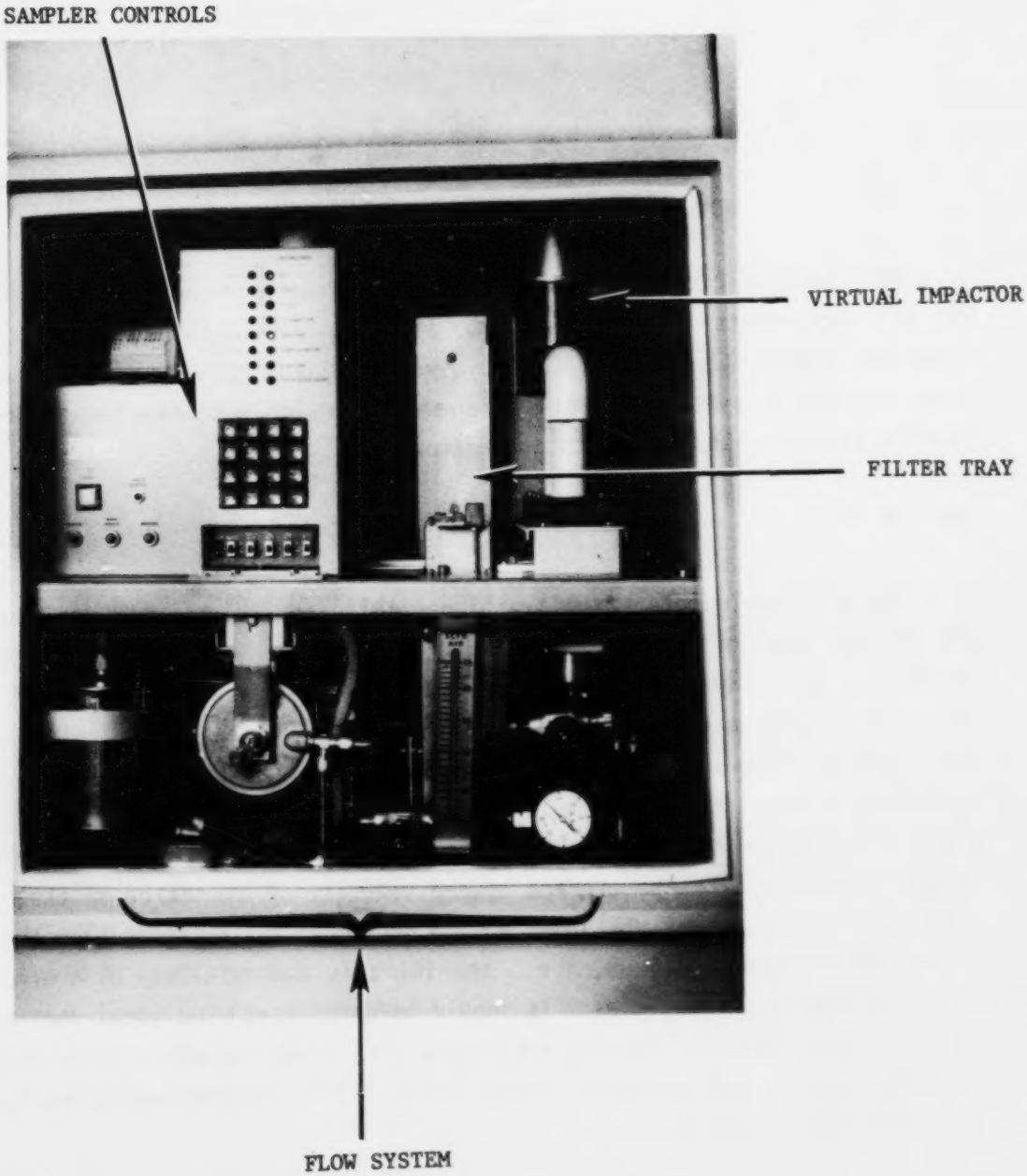

Figure 3. Beckman Dichotomous Sampler with Front Cover Removed Showing Major Subassemblies

VIRTUAL IMPACTOR

The sampled particles smaller than 15 μm pass through an inlet tube, which serves to straighten the flow, and then into the virtual impactor, which is shown in Figure 4. The virtual impactor is the basis for the operation of the dichotomous sampler and was designed by Loo et al(4). Particles entering the impactor are accelerated through a nozzle, and enter the fractionation zone. Because of their greater inertia, particles larger than 2.5 μm are drawn directly into the collection nozzle and then deposited onto a filter. The large particles do not follow the flow stream and "impact" into the low flow region of the collection tube. Because of the geometry of the acceleration nozzle, only about 10% of the total flow which enters the impactor goes through the collection nozzle. The remaining 90% of the flow, which contains the smaller particles (fine fraction), passes around the nozzle and through a tube to a separate filter.

The cut point between fine and coarse fractions depends on flow rates , the diameters of the acceleration and collection nozzles, and the distance between nozzles. Figure 5 shows collection efficiencies for the coarse particle fraction. The lower 50% cutpoint for the coarse fraction occurs at 2.5 μm. Losses of particles on the walls of the impactor are measured to be less than 10% at the cut point, which represents very good performance for a single stage virtual impactor (4).

SAMPLING FLOW SYSTEM

Atmospheric particulates are sampled through the inlet at at rate of 1 cubic meter per hour, or 16.7 liters per minute. The sample flow entering the impactor is split into two separate flow systems (see Figure 6). About 10% of the sample goes through the collection nozzle and onto the coarse filter at a rate of 1.7 liters per minute. From the filter, the air sample is carried into a ballast volume which smooths the flow for the WISA vibrator pump. Control and flow indication in the coarse flow system is provided by a needle valve and rotameter.

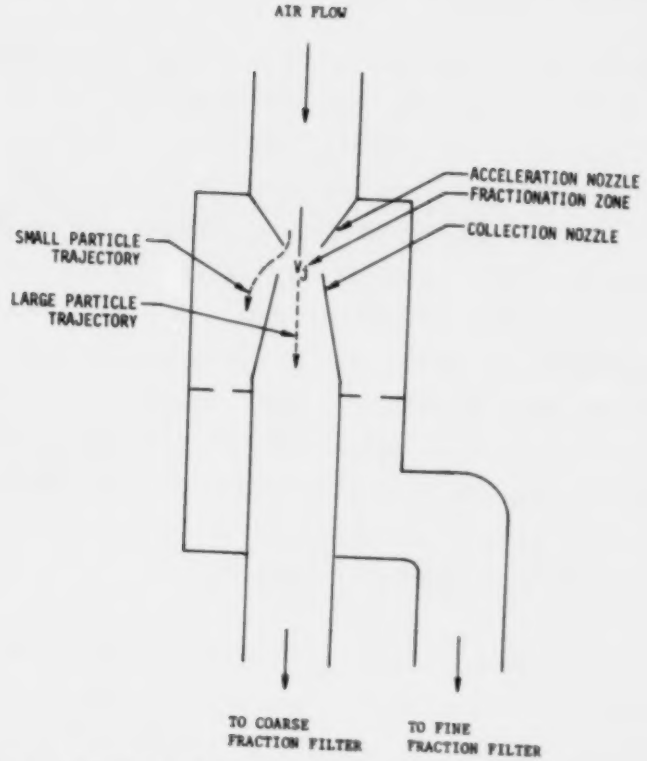

Figure 4. Sketch of Virtual Impactor Showing Separation of Coarse and Fine Flows

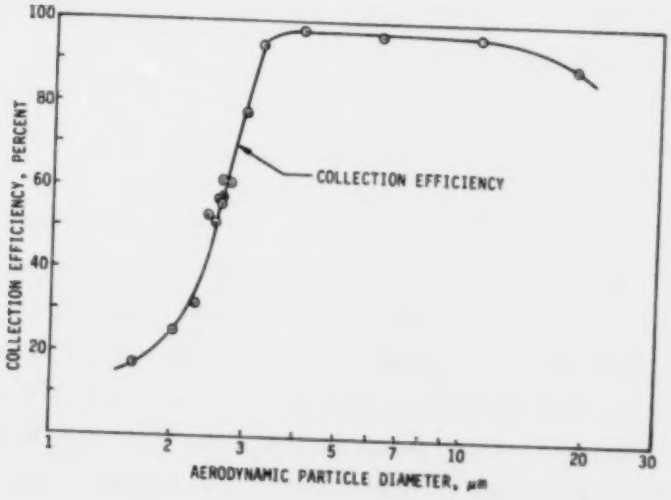

Figure 5. Graphic Representation of Virtual Impactor Collection Efficiency vs. Particle Size for a Design Cutoff of 2.5 μm

The smaller sized finer particle flow passes around the collection nozzle and is collected on a second filter at a flow rate of 15.0 liters per minute. After the filter, air goes through a flow control device which provides regulated flow in conjunction with a precision needle valve. The flow setting of 15 ℓpm is initially set by the needle valve and rotameter. The needle valve then functions as a fixed flow control orifice. A dual diaphram pump provides the vacuum necessary to induce flow through the system.

A differential pressure switch acts as a safety release in case of filter overload. The switch is connected across the needle valve to sense the loading on the fine filter (indicated as "PS3" in Figure 6). If resistance across the fine filter rises enough to cause a 5% decrease in regulated flow, then the next pair of filters is automatically inserted. This is likely if an unusually high atmospheric particulate loading exists, such as in an episode. The flow controller maintains a constant flow rate until the fine filter loading causes a pressure drop of about 20 cm (8 in) Hg. Experience has indicated that the filters are effectively fully loaded at that point (2). It should be noted that earlier production models were equipped with two additional pressure switches to detect torn or missing filters ("PS1" and "PS2" in Figure 6). Later models of the instruments do not have these switches.

Accurate flow control is extremely important in the dichotomous sampler, as the pressure drop across Teflon filters can increase rapidly as they collect particles. Maintaining the 16.7 ℓpm flow through the system is essential to maintain the particle size cutoff specifications of the inlet and virtual impactor.

FILTERS

The dichotomous sampler uses Teflon filters mounted in 5 cm x 5 cm frames with a 29 μm deposit dia., shown in Figure 7. Filters are available in two types, one in which the filters are bonded to the frames, and a second in which the filter is removable to facilitate subsequent analyses. The filters

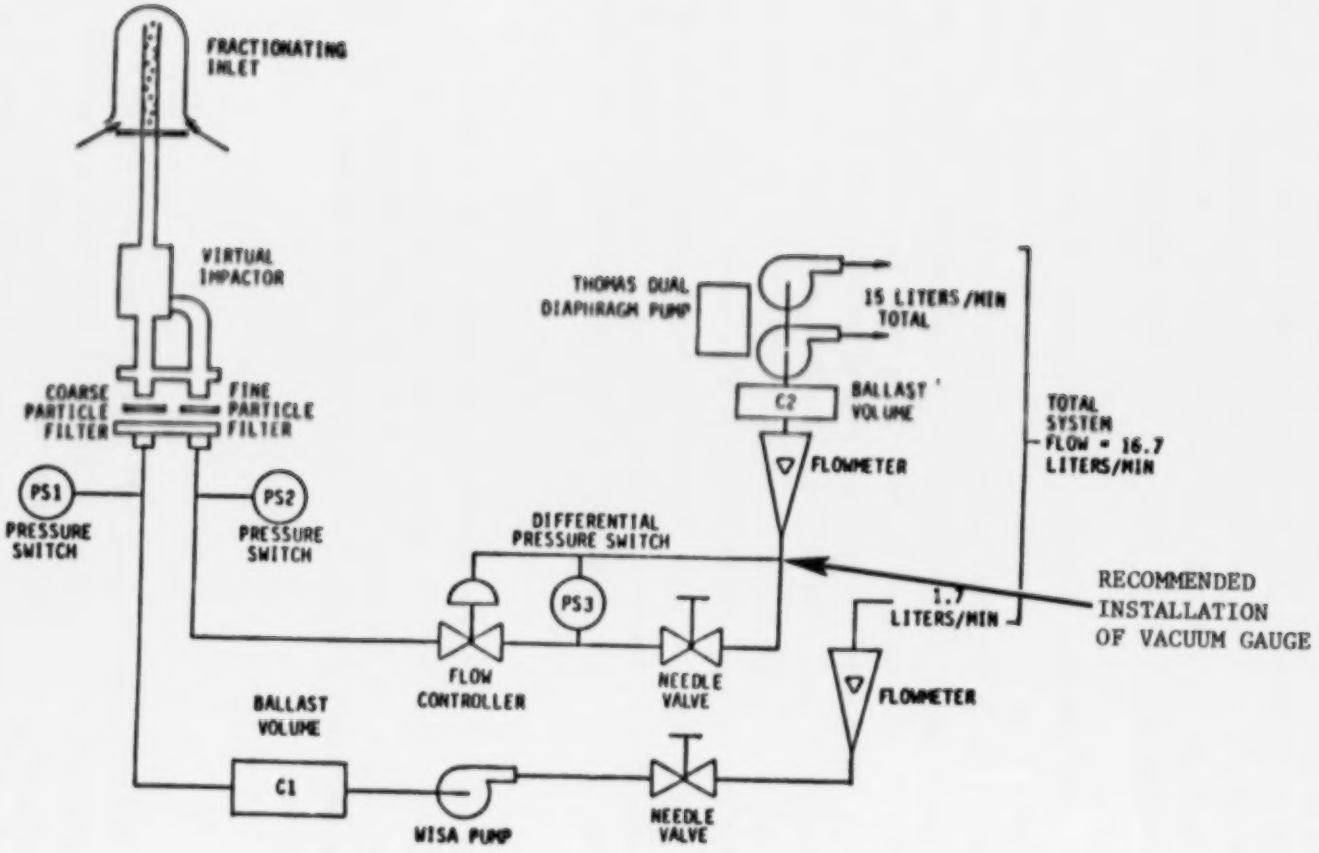

Figure 6. Sketch of Dichotomous Sampler Flow System Showing Fine and Coarse Flow Paths.

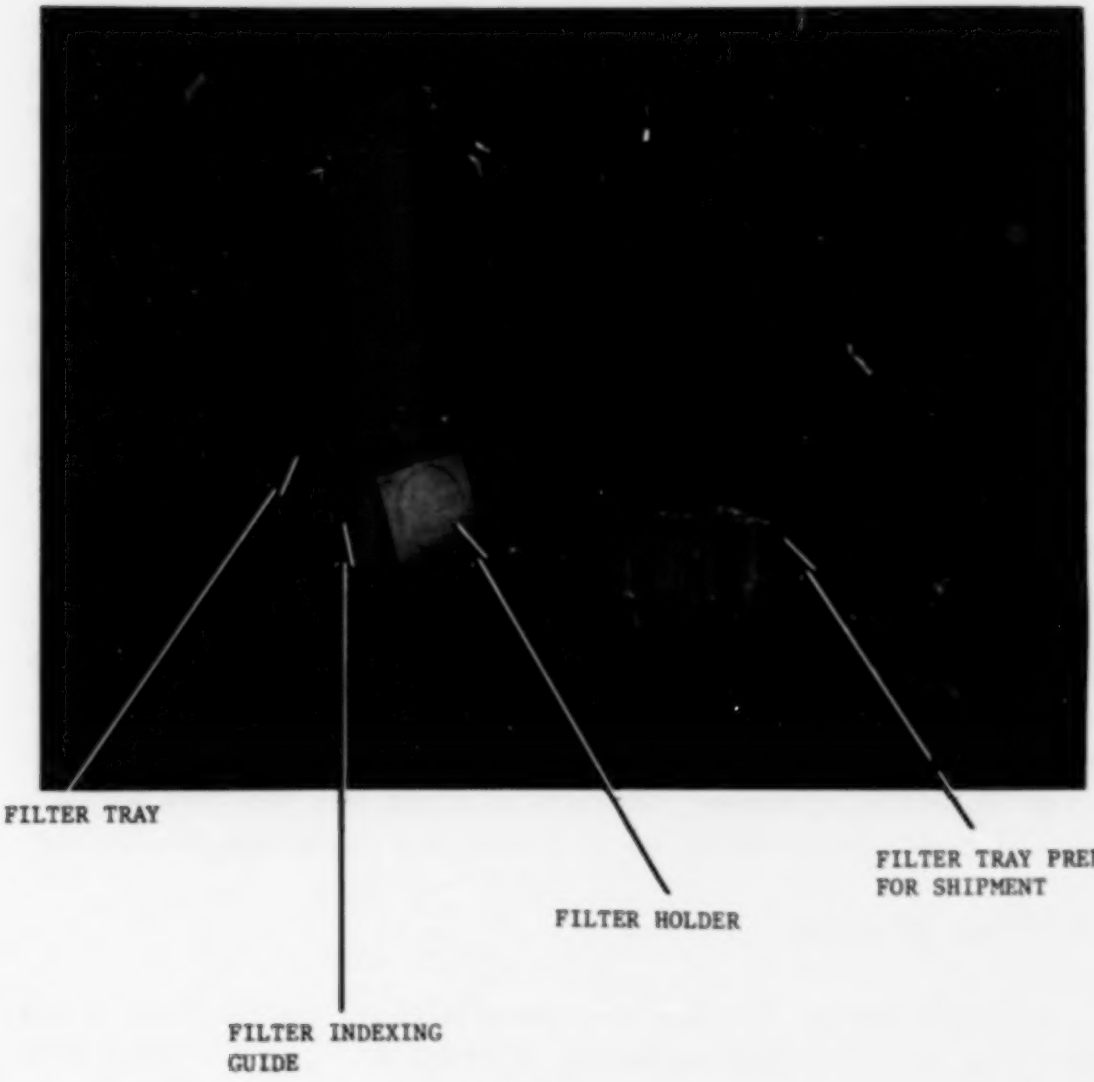

Figure 7. Filter Tray Showing Filter Holders and Indexing Guide

have a 1 μm pore size, and are preferred for their low initial pressure drop and minimal water retention. Also the Teflon material has negligible particle penetration and efficiently collects particles as small as 0.04 μm. The low weight per unit area (1 mg/cm^2) and chemical inertness make the filters suitable for XRF, β-ray densitometry and wet chemical analysis.

The filter frames are held in trays having 36 slots each. Two trays, one for the fine fraction and one for the coarse fraction, are inserted into the sample change mechanism, as shown in Figure 8. The sampler can be programmed to collect automatically up to 36 pairs of filters, but the first pair must be held blank to serve as a control. Pairs of filters are advanced by the sample changer when the preselected delay period between samples has been completed or when the flow differential pressure switch has been activated because of heavy loading on one of the filters.

Each filter is weighed and labeled with an identification number prior to shipment of the filter trays to the sampling site. It is extremely important that complete records be maintained of the samples used and of sampler operation. A suggested data collection and record keeping procedure is provided in Section 7; however, the operator should make sure that the forms and instructions appropriate to the particular sampling program are on hand.

FILTER CHANGE MECHANISM

The sample changer subsystem consists of a filter shuttle drive, a tray indexer and a filter seal mechanism, as shown in Figure 9. These three mechanisms are mechanically independent, but all are controlled by the instrument microprocessor. The filter shuttle moves back and forth, pushing the clean filters into position to collect a sample and returning the used filters to the tray. This shuttle is attached to a simple eccentric cam-actuated rotating assembly which moves the shuttle in and out of filter trays. Feedback for the position of the rotating assembly is provided by two mechanical limit switches actuated by a pin on the assembly.

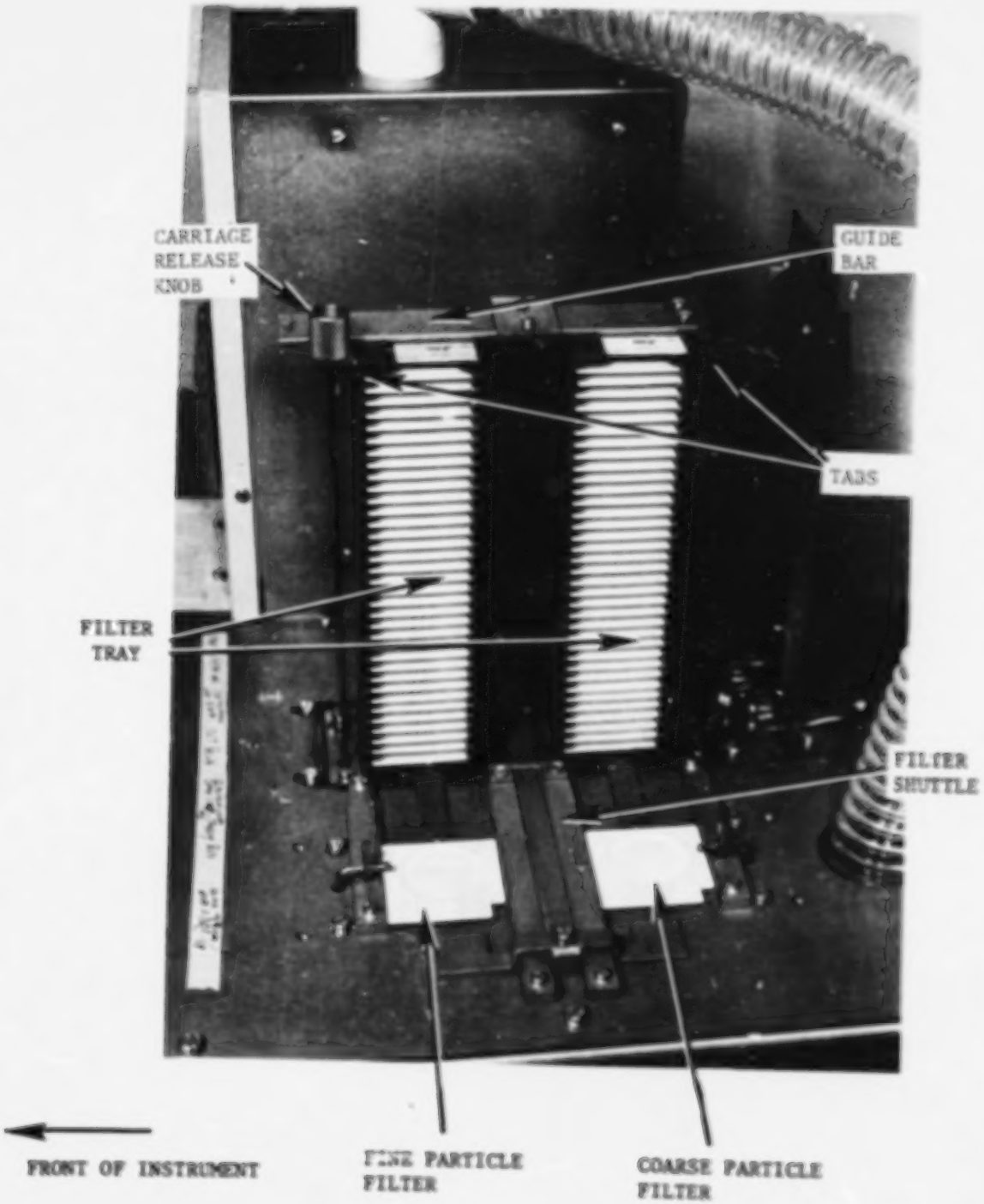

Figure 8. Interior of Sampler Showing Filter Change Mechanism, Filter Trays Inserted and Filter Pair in Place (Virtual Impactor has been removed)

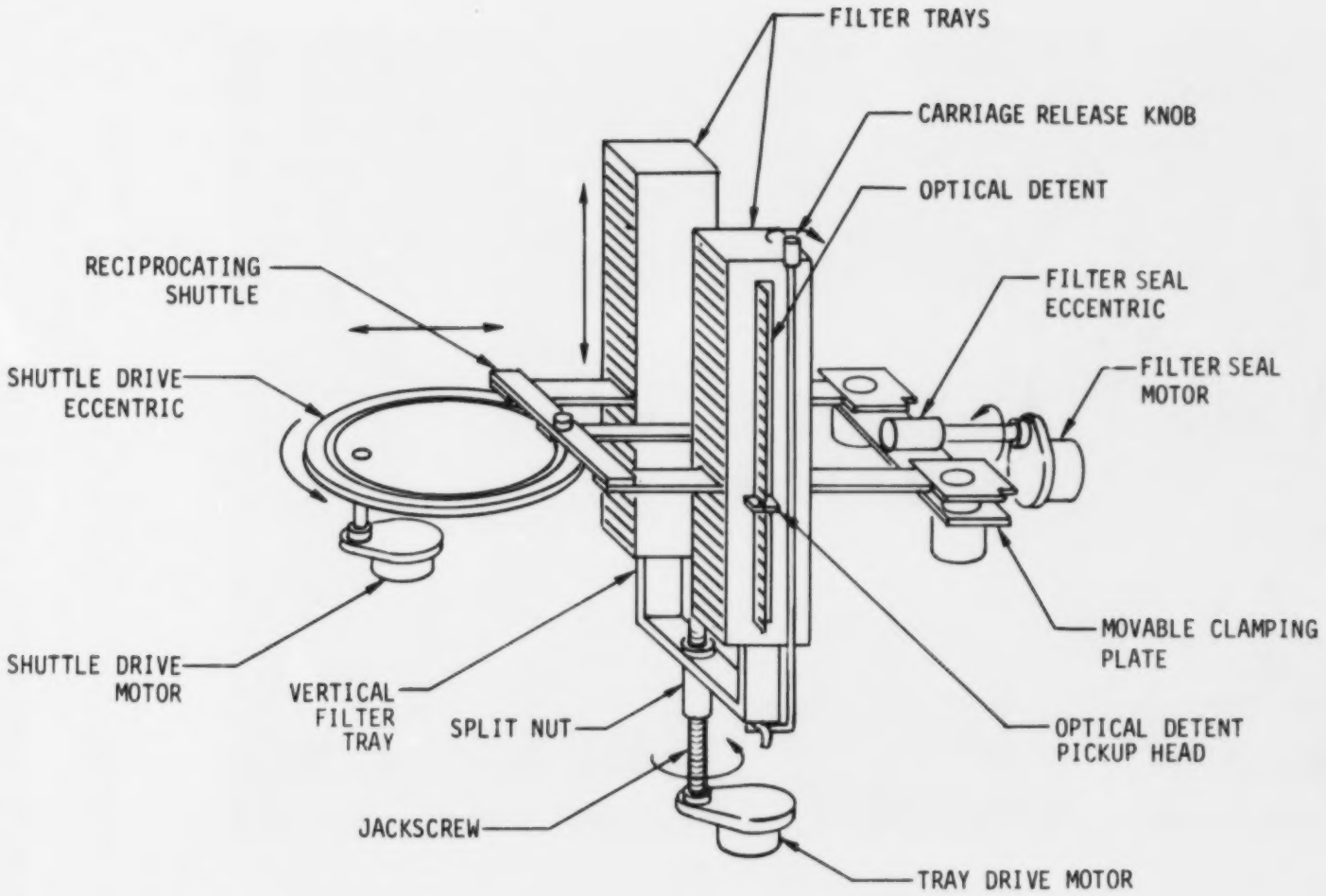

Figure 9. Sketch of Filter Change Mechanism

The filter shuttle drive only operates in the horizontal direction. Vertical movement of the filter trays is controlled by the tray index assembly so that fresh pairs of filters can be loaded in proper sequence by the filter shuttle mechanism. Vertical motion is provided by a jack-screw which engages the tray index carriage. A knob at the top of the carriage can be turned to disengage the carriage from the jackscrew to allow initial positioning of the trays. Unlike the other two mechanisms in the sample changer, the tray index assembly has multiple rest positions. Position feedback for this assembly therefore is provided by a multiposition optical limit switch rather than simple mechanical limit switches. In Figure 9 the notched optical detent and pickup head are shown on the front of the trays for clarity; however,the actual location is behind the tray, since access is not normally required (2).

The filter seal mechanism clamps and seals the filter slides into the pneumatic system once the shuttle drive has pushed them into place for sampling. It is operated in sequence with the other mechanisms under microprocessor control. Vertical motion is applied to the filter clamping tubes by a simple eccentric cam. Position feedback is provided through limit switches actuated by two eccentrics on the end of the clamp shaft (2).

Figure 8 shows the filter change mechanism with filters in place.

TEMPERATURE CONTROL SYSTEM

Sampler housing is internally heated to +33°C (91°F) using a fixed-set-point, 250-watt, proportional temperature controller. This controller will maintain the housing at the control temperature through variations in ambient air temperature from +30°C to -40°C. If ambient temperatures rise above the controller set point (+33°C), the temperature inside the housing will rise accordingly.

Besides the proportional temperature controller, several other thermal switches are included in the system to help control the internal temperature and to protect circuitry and components:

- Where ambient temperatures are very high, a high-temperature thermal switch will actuate at +48°C (+118°F) to energize the intake blower fan. The fan directs air flow over the microprocessor circuit board and associated electronics to prevent extended operation at highly elevated temperatures. This thermal switch is located inside the electronics housing assembly on the filter changing assembly (2).

- A low-temperature thermal switch disconnects both the battery power and the +5 Vdc regulated power to the microprocessor when internal housing temperatures go below 0°C. The instrument must warm up to +4°C (39°F) before power is restored. This thermal switch is located within the electronics housing on the interconnect circuit board (2).

- A third thermal switch, mounted on the underside of the instrument base plate, closes at -7°C. This connects a second 250-watt heating element to the controller, to increase internal heating for operation in extremely low ambient temperatures (2).

Figure 10 shows the thermal switch actuating temperatures and the control ranges for the Sampler. Note that a neon indicator lamp, which is visible on the front side of the power supply, is connected across the heater elements to indicate when the heaters are fully on (lamp on continuously), in proportional control (lamp flashing), and off (lamp off).

SAMPLER CONTROL SYSTEM

One of the most unique features of the Beckman dichotomous sampler is its Microprocessor Control System, shown in Figure 11. The microprocessor generates a sequence of timed comands which control the visual display, lights, keyboard, printer, motors, and pumps. The total sampler operation is controlled by an 8-bit microprocessor-based system using an 8085 Central Processing Unit (CPU). Control programs are stored in 4K of Read-Only memory.

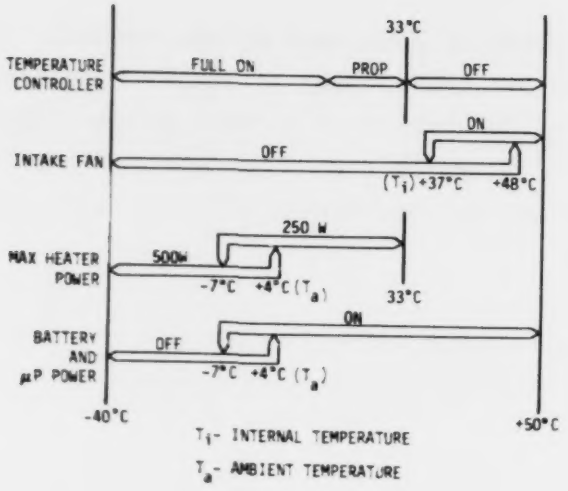

Figure 10. Diagram Showing Temperature Control Ranges and Switch-Actuating Temperatures

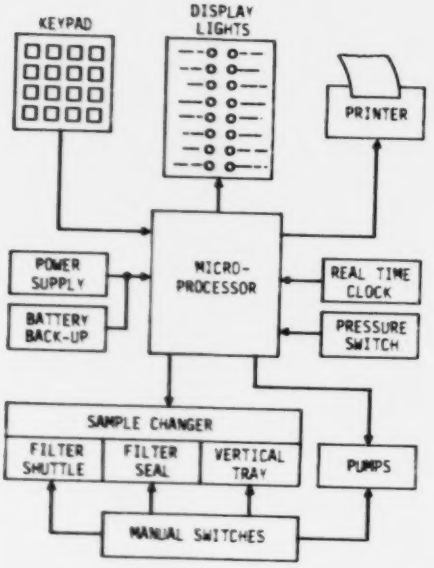

Figure 11. Simplified Electronic Control System Diagram

The microprocessor board power requires a single +5Vdc supply, with battery back-up (2).

Sampler operation is programmed by the key pad. Current data and time, sample start time and date, number of samples, and time between samples are entered, following the sequence indicated by the display panel lights. The printer provides a record of sample parameters. Manual switches are included to actuate the filter shuttle, filter seal, vertical tray index mechanisms and the sampler pumps.

A more detailed description of the key pad display lights and manual switch functions is included in Section 6, Operating Procedures.

SECTION 3

CONSIDERATIONS IN SITE SELECTION

SITING CRITERIA

Selection of the sampling site and sampler location is dependent on the intended use of the collected data, as well as several other considerations. This section provides criteria and a suggested methodology for site selection. The information is based on the recommendations of the EPA's Standing Air Monitoring Work Group (SAMWG) and the final regulations on ambient air quality monitoring (5). Appendices D and E of reference (4) discuss network design and sampling probe siting criteria, respectively, and should be reviewed prior to establishing the monitoring site. Another valuable reference is the report of Ludwig, Kealoha and Shelar (6).

A dichotomous sampling program can serve a variety of objectives. The dichotomous sampler gives information on the coarse and fine fraction of suspended atmospheric aerosols below 15 μm in diameter. These fractions may have similar or different sources. These sources may be local or distant. One size fraction may reflect variations in local sources and dispersion conditions while the other fraction does not. Therefore, in choosing a site consideration must be given to factors that might bias measurements and compromise sampling objectives.

In siting dichotomous samplers two general categories of impacts should be kept in mind. Meteorological (mesoscale and microscale) effects and local source configurations might influence fine and coarse particle levels.

Meteorological factors on the local scale are the altered wind flow patterns or mixing conditions by topographic features. Tables 1 and 2 are included to highlight these considerations.

TABLE 1. Topographic and Meteorological Influences on Local Dispersion

Topographic Features	Effects
1. Elevated regions	a. Increased wind speed (and increased ventilation) over hill tops. b. Occasional impacting of elevated plumes on ground level.
2. Deep valleys	a. Channeling of wind flow along the valley axis, resulting in higher average concentrations in the valley. b. Development of stable, drainage winds during calm, nighttime conditions, resulting in higher concentrations along the valley floor.
3. Undulating regions	a. Increased atmospheric turbulence near the ground level during time of moderate or strong winds. This results in lower pollutant concentrations at locations near sources. b. Accumulation of pollutants in low spots during calm, nighttime conditions (i.e., localized drainage wind conditions).
4. Regions of tree cover	a. Enhanced turbulence near the ground during moderate or strong winds, resulting in lower concentrations for locations near sources. b. In fully covered regions, blockage of elevated plumes, resulting in lower concentrations at ground level.
5. Bodies of water	a. Increased moisture content in the local atmosphere, favoring fog formation at low-lying spots, and affecting the removal rate of SO_2 and other pollutants from the atmosphere. b. For larger bodies of water, formation of local circulation (lake and sea breezes) which can cause ground level fumigation on the landward size of sources, during sunny daytime conditions.

TABLE 2. Source Configuration and its Influence on Dichotomous Sampling

Source	Effects
1. Unpaved roads, sanded or salted open fields, stockpiles sand, etc.	Resuspension of surface dust roads, contributing to coarse fraction.
2. Heavy traffic on nearby road	Resuspension of coarse particles, local source of fine particles high in Pb, Br.
3. Overhanging trees -- beneath densely forested canopy	Some possible filtration of coarse particles; also production of pollens.
4. Rooftops, gravel roofs	Building exhaust vents, local chimney emissions. Possible resuspension of roof material.
5. Building wakes	Possible influence of wake capture of building emissions.

INSTALLATION REQUIREMENTS FOR THE DICHOTOMOUS SAMPLER

Installation requirements for the dichotomous sampler are minimal. It is designed to operate outdoors, through a range of ambient temperatures of -40° to 122°F. The internal heating blower system essentially eliminates the need for external temperature or humidity control. Although the instrument is housed in a weather-tight shelter, it may also be placed indoors. This will facilitate calibration and maintenance and protect the filters during handling. Indoor installations require the availability of a level, flat, rigid surface to support the four legs of the shelter, and some modifications to the sampler inlet standpipe. Indoor installations also require access to the ambient air directly above the sampler to allow placement of a straight pipe to the fractionating inlet. Provisions should be made to provide enough clearance above the sampler to allow removal of the shelter which must be lifted up and over the instrument.

The instrument weighs less than 200 pounds and can be lifted by two persons using the grip handles on the sides and rear and the upper lip of the front door of the shelter. It can be plugged into any grounded 115 Vac electrical outlet and requires no further utility connections.

As with the placement of other particulate samplers, the inlet for the dichotomous sampler must be located 2 to 15 meters above the ground (5). Two meters is considered minimum height necessary to avoid entrainment from dusty surfaces; the 15 meter upper limit is essentially a compromise between the desire to have instruments that are most representative of population exposures and the practical considerations of site security and accessibility. Further, the inlet should not be within two meters of walls or other obstructions or within 20 meters of large trees which often provide surfaces for particle deposition and restrict airflow.

Since the dichotomous sampler may be co-located with hi-vol samplers it is recommended that the dichotomous inlet be placed so that it is not within two meters of and at least 0.5 meters above the hi-vol. This will reduce the collection of copper and carbon particles from the hi-vol motor. If possible, exhaust from the hi-vols should be ducted away from the dichotomous sampler by using a large flexible hose or similar device attached to the bottom of the hi-vol motor housing.

SECTION 4

INSTALLATION PROCEDURES

DELIVERY AND UNPACKING

Although the sampler is inspected and packed to protect it during shipment, there is always the possibility of damage. Carefully inspect the shipping package for any external signs of damage, note this information on the delivery receipt, and have the delivery person sign all copies of the receipt before leaving. Unpack the instrument and check each item against the packing slip to make sure everything has been included in the shipment.

As soon as possible, the sampler should be assembled and checked out to verify that there is no internal damage. Experience has shown that the filter change mechanism is more likely to be damaged in transit than other assemblies. Also, the shelter housing legs may be bent or broken, and the plastic caps used to plug the former location of two pressure switches in the flow lines (see Figure 20) may become dislodged or lost. These caps must be in place before sampling.

If there is any indication of either internal or external loss or damage to the sampler, the shippping company and manufacturer's sales representative should be contacted <u>immediately</u> before any further use of the sampler.

SAMPLER INSTALLATION

Before starting the actual installation, make sure the site location and instrument placement meet the criteria and requirements described in Section 3 of this report.

Outdoor Installation

The Beckman dichotomous sampler requires no special installation procedures if it is to be used outdoors. The instrument should be placed on a firm, level supporting surface and securely anchored. High wind speeds in excess of 50 mph can cause the sampler to tip over. Be sure to provide several inches of clearance below the sampler housing, as the interior air circulation ports are loacted in the base plate. The fractionating inlet is attached to a sampling standpipe, which is inserted through the top of the sampler housing. The standpipe should be lined up and firmly butted against the impactor inlet. Use a flexible sleeve or a 2-inch length of 1¼" I.D. tygon tubing as shown in Figure 12 to connect the standpipe and the impactor. The clamp located on the underside of the shelter housing top should then be tightened to hold the standpipe in place during sampling. There should not be any space between the standpipe and impactor in order to maintain a smooth air flow into the impactor. Once the standpipe and inlet are installed, the sampler may be plugged into a grounded 115 VAC electrical outlet, it is then ready for checkout and operation.

Indoor Installations

Although the dichotomous sampler is designed for use outdoors, it can be located inside a building, instrument shelter or trailer. This type installation requires minor modifications of the instrument but may be preferable in some sampling situations. If an indoor installation is selected, the fractionating inlet must be located in the ambient air directly above the impactor. This requires an extension to the inlet standpipe and a fixed supporting sleeve through which to raise and lower the standpipe. A typical installation is shown in Figure 13.

The standpipe extension should be made of rigid piping with a nominal 1" inside diameter and 1¼" to 1 3/8" nominal outside diameter. The standpipe and extension together should be long enough so that the sampler inlet will be at least 2 meters above the sampling station roof when the unit is in operation.

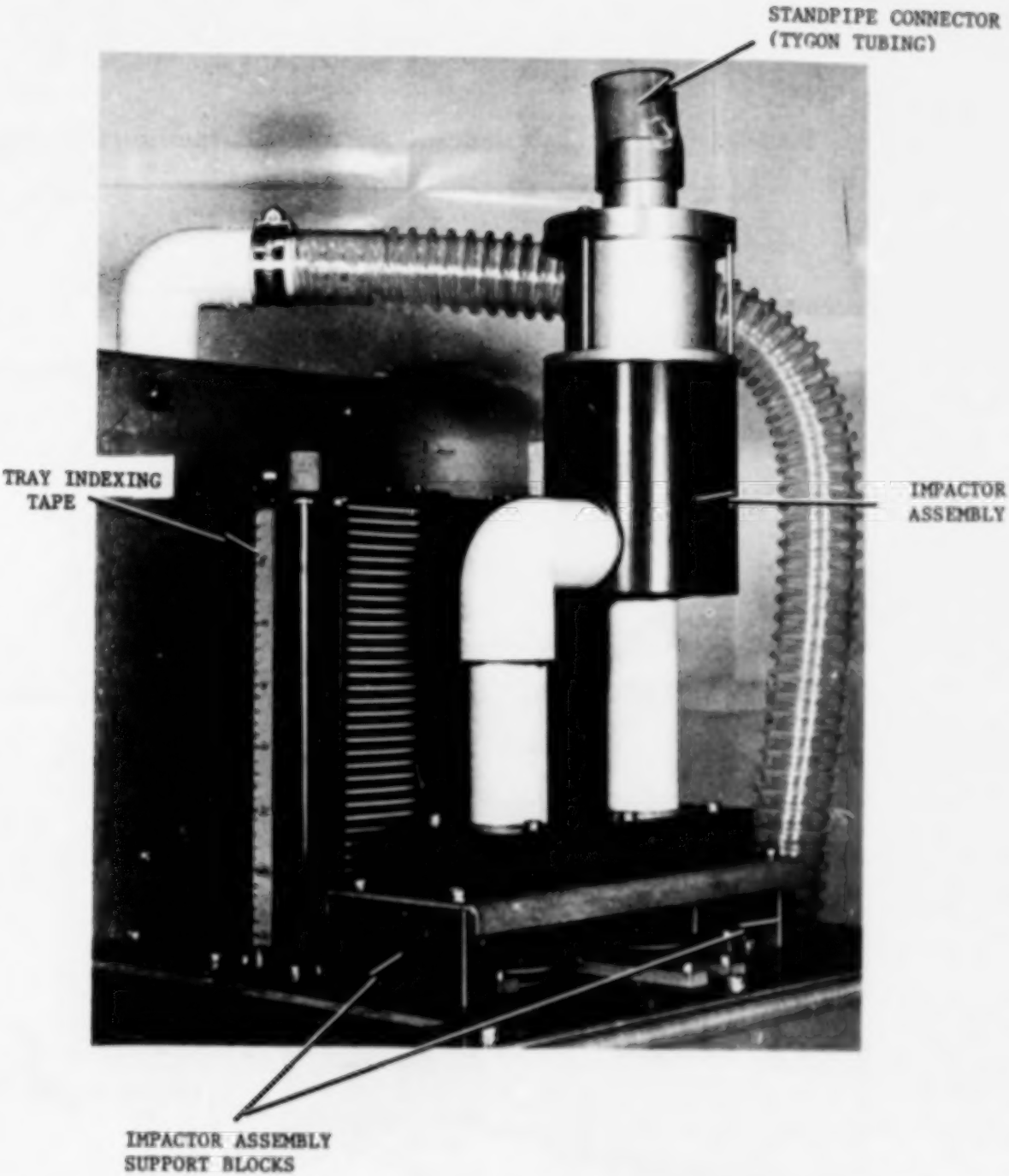

Figure 12. Interior of Sampler Showing Filter Tray and Virtual Impactor Installed. (Note section of Tygon tubing at top of Impactor for connecting to standpipe; also note tray indexing on side of filter tray.)

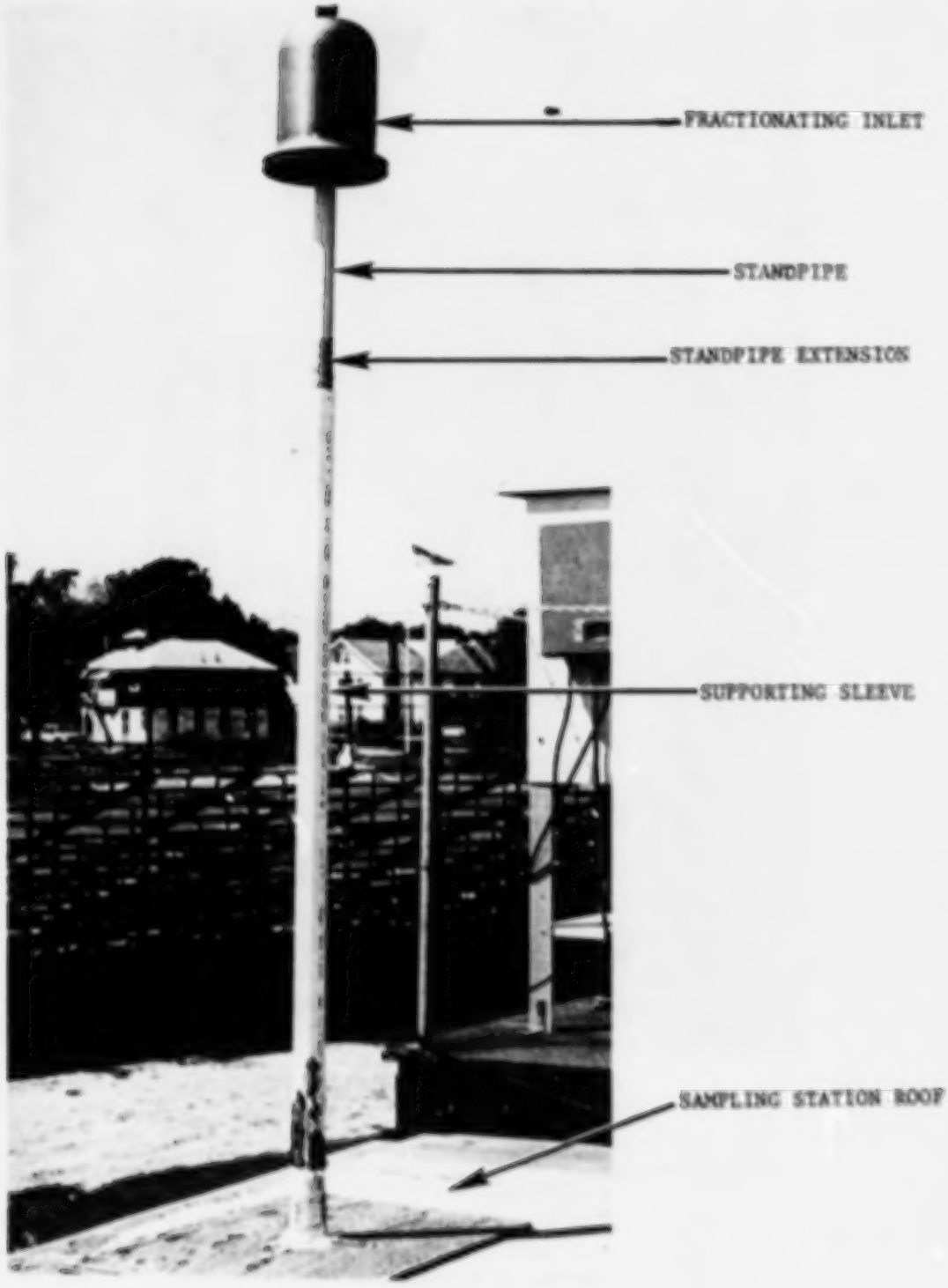

Figure 13. Standpipe Extension and Supporting Sleeve as Required for Indoor Sampler Installations

The extension may be attached to the standpipe by using a section of 1¼" tygon tubing or other suitable material, clamped to the standpipe and the extension. Be sure that the extension and standpipe are firmly butted together so that no flow irregularities are induced.

Material selected for the extension tubing is a concern because of potential wall losses along the additional length. Stainless steel tubing will reduce this potential, but may not be practical or readily available. If PVC pipe is used, large wall losses can be expected. Aluminum pipe is satisfactory if great care is taken to prevent aluminum (from the pipe walls and especially pipe ends) from falling into the sampling stream.

Since the standpipe must be free to be raised and lowered to the impactor, it cannot be fixed to the roof of the sampling station or trailer. A rigid sleeve which is firmly attached to the roof must be provided (see Figure 13). Make the sleeve out of PVC piping to minimize the possibility of metal particles becoming dislodged as the standpipe is moved. The inside diameter should be sufficient to allow free movement of the standpipe and extension once they are joined together. The supporting pipe should be tall enough so that the inlet rests on the top of the pipe during sampling. The pipe may be fixed to the roof by metal brackets such as in Figure 13 or by guy wires.

Once the standpipe extension and supporting sleeve are installed, the standpipe should be lowered onto the impactor and connected by use of flexible sleeve or section of 1¼" I.D. tygon tubing, as was shown in Figure 12. The clamp located on the underside of the sampler housing top should be tightened to hold the standpipe in place during sampling. Be sure that there is no space between the standpipe and impactor in order to maintain smooth air flow into the impactor. Once the standpipe is attached, the sampler can be plugged into a grounded 115 VAC electrical outlet and is then ready for checkout and operation.

For the convenience of the operator, it is suggested that a muffler be installed on the pump exhaust to reduce noise level in the sampling building. Several types of mufflers are available. Appendix I describes one of these that has proven to be effective in field tests.

Note: It is strongly recommended that a worm drive circulator clamp be used to hold the standpipe and impactor inlet together. The clamp should be placed around the two inch tygon tubing section which is used to join the inlet and impactor.

Description and sources for accessories and materials discussed in this report are provided in Appendix I.

CAUTION

Always turn the POWER switch off before disconnecting the power cord. Otherwise, the battery backup system will be activated; after 30 minutes, the batteries will be completed discharged.

SECTION 5

CHECKOUT AND CALIBRATION

Since performance of the virtual impactor is highly dependent on the flow rate through the sampler, it is critical that precise flow calibration and accurate flow control be accomplished. Thus, it is essential that the system be carefully checked out and calibrated prior to initial sampling and at regular intervals thereafter as suggested in Section 8 of this report. This section provides instructions and recommendations for initial checkout of the sampler. It also includes procedures for calibration of the fine and coarse flow rates, and for total flow system checks. To perform the tests and calibrations described here, the operator must be familiar with the operating procedures described in Section 6.

INSTRUCTIONS FOR SAMPLER CHECKOUT

1. Once the instrument is unpacked and set up, an operation check of the printer and system controls should be performed to verify that no damage has occured to the internal mechanisms. The operator should complete Items 2 through 11 of the operating instructions in Section 6, and check carefully that the light sequence, printer output, clock and other controls are working properly. It is not necessary to unpack and load the filter trays for this checkout step.

2. The virtual impactor assembly should be removed and cleaned in accordance with the instructions in Section 8. Once the impactor is reassembled and installed, the impactor inlet should be covered with a #7½ or #8 rubber stopper, aluminum foil, or a similar device so that dirt and other

foreign objects will not inadvertently enter the impactor. NOTE: The inlet should always be covered when the sampling standpipe is removed.

3. It is strongly recommended that a vacuum type pressure gauge (see parts list in Appendix I) be installed in the flow sytem, located as shown in Figure 20. To install, locate the tee type fitting which is at the lower right of the fine flow rotameter. Note that one part of the tee is plugged. Remove the plug and install the vacuum gauge. Be sure that no "stringy" pieces of Teflon tape are left in the tee fitting after the plug has been removed. Position the gauge dial so that it can be read easily at the same time as the rotameters.

4. Since the flow checks and calibrations described below will be performed with a pair of filters (not the first set, #1) in place, each filter tray should be checked for damaged filters. Early models of the Beckman sampler contained pressure switches to sense torn or missing filters. However, later production models do not have this feature and each filter must be checked prior to loading of the trays. NOTE: The filters should be handled carefully using the filter frames. The Teflon collecting surface should never be handled directly.

5. To assist in indexing the filters in the trays, it is suggested that a piece of tape be placed along the front edge of the filter tray, and markings located on the tape to correspond with the filter numbers 1-36. Figure 12 shows a typical installation.

6. All flow checks and calibrations should be performed after the sampler door has been closed and top unit turned on for at least 2 hours. This will allow the instrument to reach its normal operating temperature. The power switch should be turned on; however, it is not necessary to turn the pumps on. Also, the unit should be run for at least 15 minutes with filters in the sampling position and the front access door closed.

7. After the instrument is warmed up, the filter seal system must be checked for leaks. Insert a pair of filters (not the first filter set) and close the filter seal mechanism using the manual switch. Turn on the pumps and plug the flow through the virtual impactor by either inserting the rubber stopper or by inserting the calibration adaptor described in Appendix I and closing the adaptor valve. Flow through both the fine and coarse flowmeters should drop to zero. If any flow is indicated, the filter seal mechanism should be checked. The limit switches on the filter seal mechanism and the seal tube height can be adjusted following the instructions provided in Section 6.2.3 and 6.2.4 of the manufacturer's manual (2).

   Another possible source of flow leaks is in the blocks that support the impactor assembly (see Figure 12). In later production models these supports were machined down 0.03 in. to provide a tighter seal around the filters. Operators of early models of the instrument should consider retrofitting their samplers with the modified support blocks (after contacting the factory) if a flow leak is indicated.

   If the seal mechanism is adjusted properly and there are no loose or damaged fittings or tubing but leaks are still present, the manufacturer's service department should be contacted for further troubleshooting. If no leaks are indicated but the flow cannot be adjusted to obtain 15 liters per minute through the fine flowmeter, there may be a problem with the flow controller or the pump, and again the manufacturer should be contacted for further instructions.

8. Once the system has been checked for flow leaks and adjusted, if necessary, calibration of the fine and coarse flow system should be accomplished using one of the methods described below. The flow measuring devices selected for the calibration must be suitably calibrated themselves (e.g., standard NBS bubble meter for low flow, and lab-type calibrated spirometer for high flow measurement equipment) before being used to calibrate the dichotomous sampler.

NOTE: Since flow measurements are highly sensitive to temperature conditions, equipment used in calibrations and the sampler should be at comparable temperatures during calibration. Allow equipment to equilibrate in the sampler operating environment for about two hours prior to proceeding with the calibrations.

INSTRUMENT CALIBRATIONS

Instructions are provided below for two methods of fine and coarse flow calibration for the dichotomous sampler: The first uses ball-in-tube rotameters, and the second uses a Singer Model DTM-115-3 dry test meter. For the rotameter calibration system, flow calibrations are to be made at a point above the filters (referred to as "at inlet") and a point below the filters ("at base"). This will assist in detection of leaks in the filter sealing mechanism. It is important to note that leaks in the filter seal area cannot be detected by the sampler's built-in flowmeters. For the dry test meter method, flow calibration is made only at the inlet because it is not practical to perform flow checks both above and below the filters. If the flow check and inlet flow calibration are done according to the instructions for the Singer meter, then adequate leak detection will have been accomplished.

Descriptions, specifications, and supply sources for equipment used in these procedures are presented in Appendix I.

CALIBRATIONS USING ROTAMETERS

It is recommended that Types 603 and 604 rotameters as described in Appendix I be used for calibrations. As with all rotameters, they must be corrected to temperature and pressure conditions at the sampling site. This is most important when the rotameters are being used outside in cold weather and/or high altitudes. For the 603 and 604 rotameters, pressure and temperature correction tables are provided in Appendix II; if other flow meters are used, see that manufacturer's recommended procedures.

The operator is cautioned to review Item Number 6 under "Instructions for Sampler Checkout" to ensure the instrument is adequately warmed up prior to calibration. Also, the instrument must be checked for leaks in accordance with Item 7 of the checkout instructions before proceeding.

Caution: To avoid possible damage to the pumps do not operate the sampler for more than 20 minutes with the valves closed.

Fine Flow Calibration (at Base)

1. Attach the 604 rotameter to the polyethylene vacuum tube at the base of the fine flow tube on the side of the filter change mechanism closest to the front access door, as shown in Figure 14. This is accomplished by loosening the Swagelock fitting at the 90° elbow, removing the tube from the elbow, and attaching it to the 3/8" adaptor fitting (described in Appendix I). The adaptor is then inserted into the heavy walled ¼" vacuum tubing, and the tubing is attached to the 604 rotameter.

2. Once the tubing has been attached, the rotameter leveled, and the operator is in a position to view easily both the 604 and fine flow rotameters, the sampler pumps should be turned on.

3. Adjust the fine flow control valve (see Figure 20) to obtain air flow of 15 ℓpm on the 604 rotameter usiing the calibration curve provided with the 604 meter. Allow the system to run at this flow rate for 5 minutes.

4. Record the observed flow readings of both the 604 and fine flow rotameters, and of the vacuum gauge.

5. Using the fine flow control valve, adjust the flow through the 604 rotameter to obtain readings for two flow rates above 15 ℓpm and two below. Record indicated flow readings for both the 604 and the fine flow rotameters for each point. Also record the vacuum gauge reading at each point. Using the 604 rotameter calibration curve, determine true air

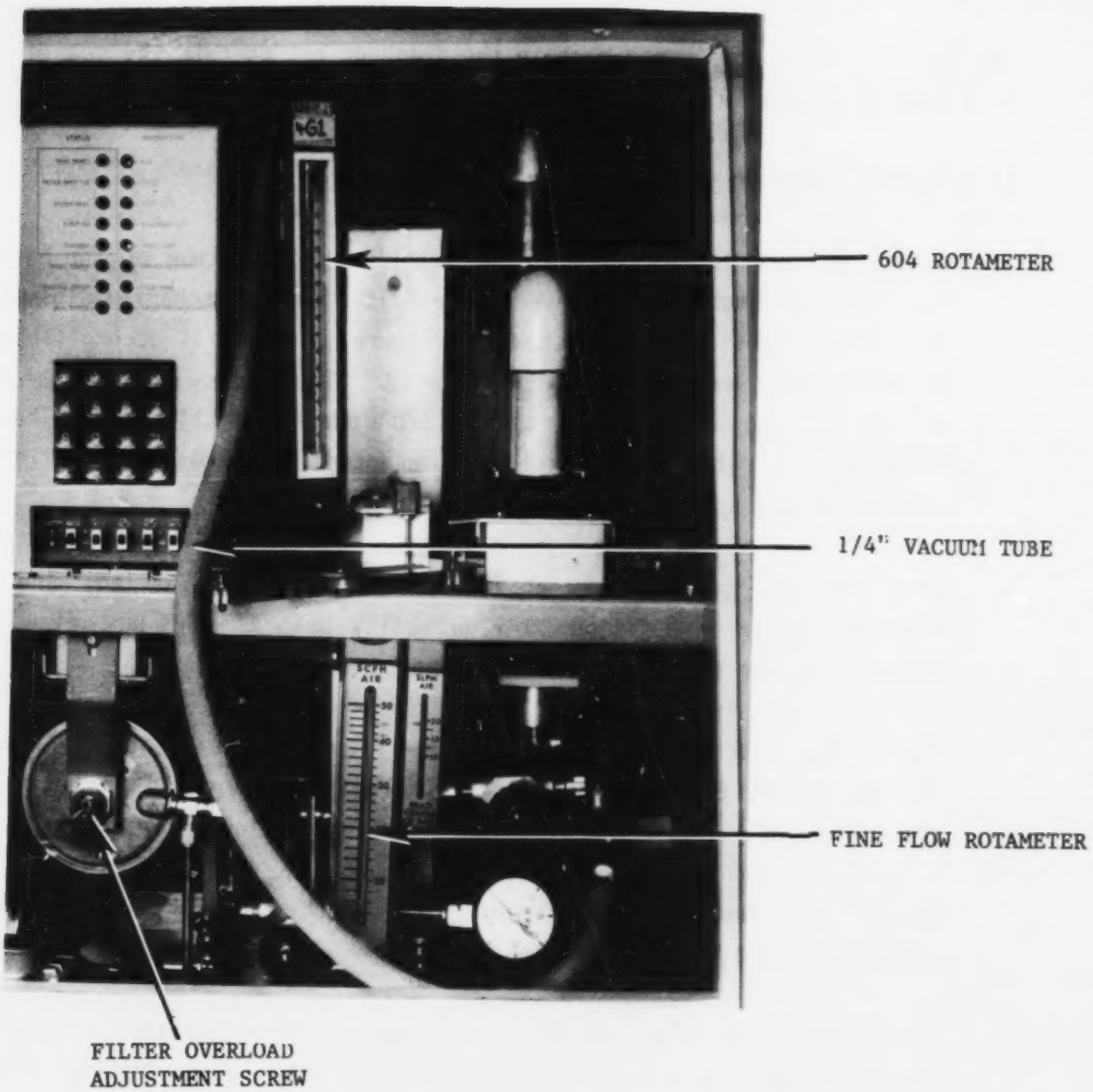

Figure 14. Typical Installation for Fine Flow Calibration at Base Using 604 Rotameter

flow for each point, and plot the indicated versus actual flows. Figure 17(a) shows a sample form that will simplify data recording and plotting. Separate forms are necessary for the fine and the coarse flow calibrations.

6. Draw the calibration curve and determine the proper fine flow rotameter set point to obtain an actual flow rate of 15 ℓpm.

7. Return the 3/8" polyethylene tube to the 90° elbow Swagelock fitting and tighten securely.

Fine Flow Calibration (at Inlet)

1. Attach the 604 rotameter to the valve of the inlet adaptor tube (described in Appendix I) with the heavy wall vacuum tubing, making sure that the valve is fully open (counter-clockwise), as shown in Figure 15.

2. Insert and seal a clean set of filter (not filter set #1) into the filter mechanism.

3. Turn the coarse flow control valve (Figure 21) off (clockwise) so that only fine flow is being drawn through the inlet.

4. Adjust the fine flow rotameter to read the 15 ℓpm set point which was determined at the base calibraiton. If the 604 rotameter does not give the same reading as it did during the base calibration, the seal mechanism is suspect of a leak and may need adjustment [see Sec. 6.2.3-4 of Beckman Manual (2)].

5. If the same reading is found, proceed to adjust the fine flow valve to obtain two points above 15 ℓpm and two points below as before. Record these data including the vacuum gauge reading on the fine flow calibration form in the "At Inlet" section, Figure 17(a).

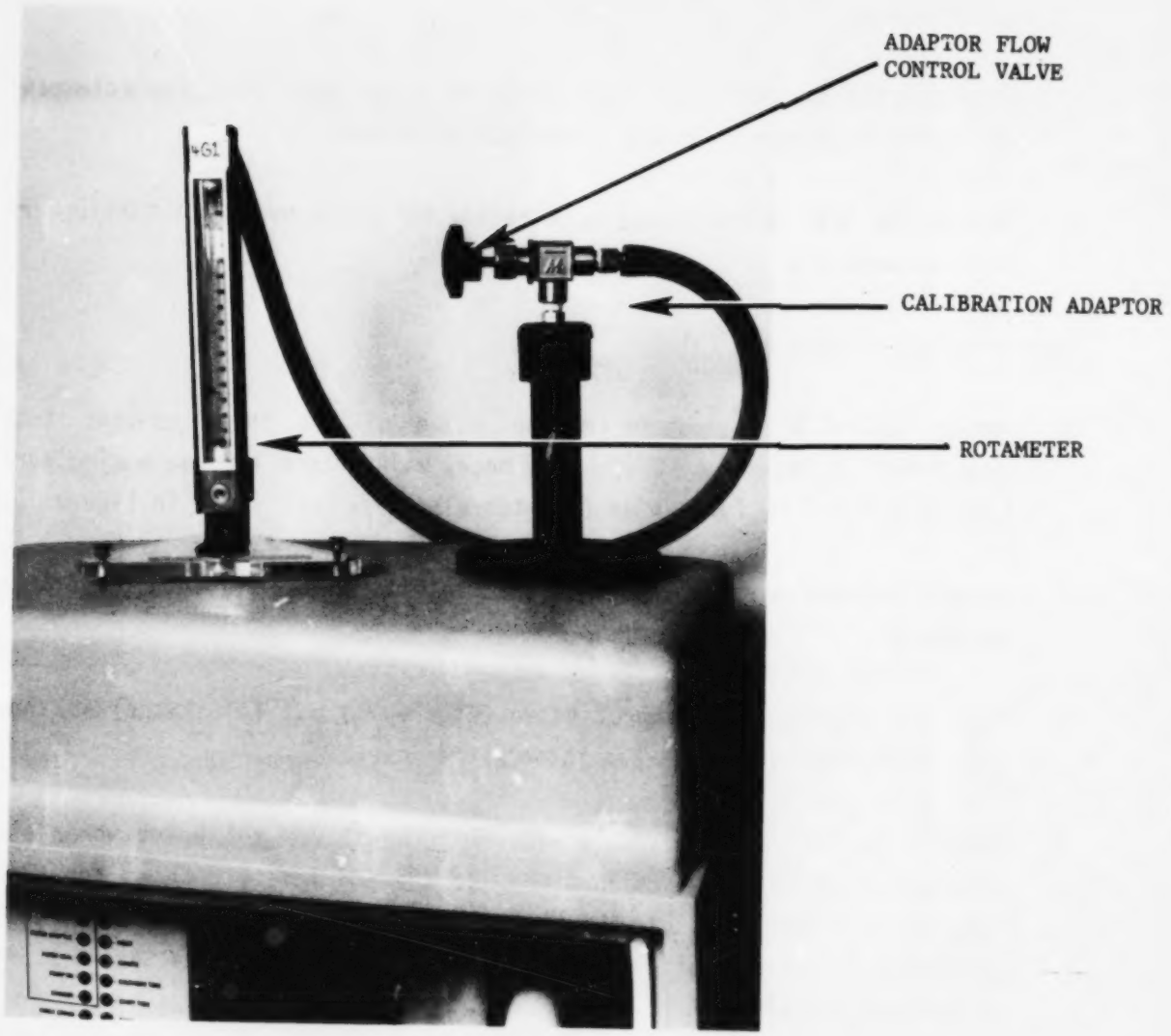

Figure 15. Typical Installation for Fine Flow Calibration at Inlet Using 604 Rotameter, Showing Calibration Adaptor.

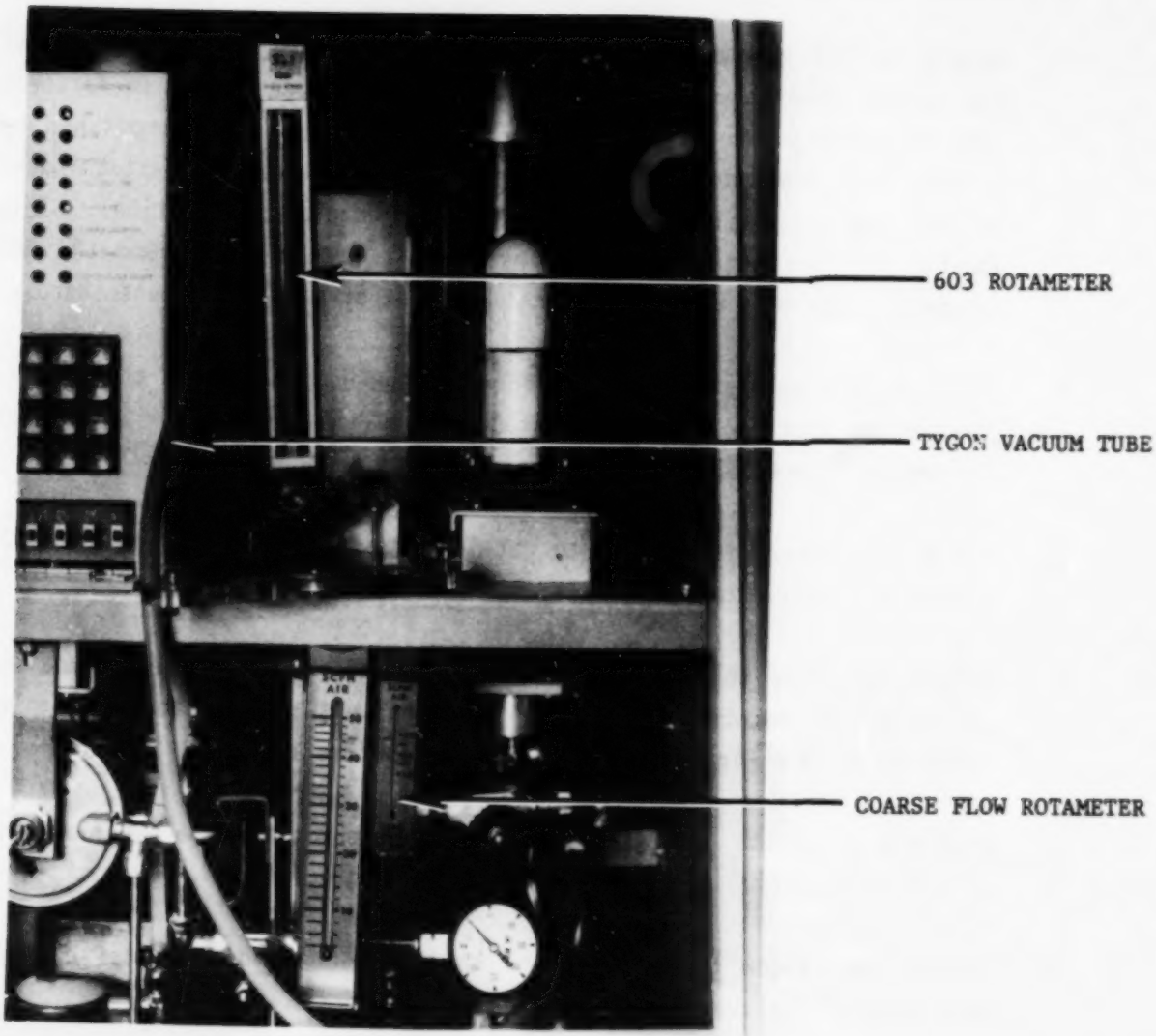

Figure 16. Typical Installation for Coarse Flow Calibration at Base Using 603 Rotameter

6. Again plot the points which should be similar to the "At Base" curve. From both curves determine the proper set point.

Coarse Flow Calibration (at Base)

1. Attach the 603 rotameter to the "Tygon type" vacuum tube at the base of the coarse flow tube, the side of the filter change mechanism farthest from the access door as shown in Figure 16. This is accomplished by pulling the Tygon tubing off the nipple at the 90° elbow and attaching it to the adaptor nipple (See Appendix I for adaptor description). This adaptor is then attached to the heavy wall vacuum tubing and the 603 rotameter. Be sure that the Tygon tubing is not pinched or bent sharply.

2. Once the tubing has been attached and the operator is in a comfortable position to read both the 603 rotameter and the coarse flow rotameter, the sampler's pumps should be turned on.

3. Adjust the coarse flow valve to obtain a reading of 1.7 ℓpm on the 603 rotameter. Allow the pump to run for 5 minutes.

4. Adjust the valve to obtain readings for two points above 1.7 ℓpm and two points below. Record this data on the coarse flow dichotomous sampler calibration form Figure 17(b) in the "At Base" section.

5. Plot the curve and determine the proper set point to obtain a flow rate of 1.7 ℓpm.

6. Return the "Tygon type" tubing to the 90° elbow and check to see that both ends of the tube are firmly attached.

FINE FLOW DICHOTOMOUS SAMPLER CALIBRATION Site:_____ Date:_____

DICHOT.

Ser. No._____

Last Calib._____

Current Temp._____

Current Press._____

By_____

Low flow cut out switch set at_____lpm

CALIBRATOR TYPE_____

Ser. No._____

Last Calib._____

Temp._____

Atm. Press._____

	Dichot. Rotameter Indicated	604 Rotameter Indicated	Actual lpm	VAC. ins.
At Base				
At Inlet				

Remarks:

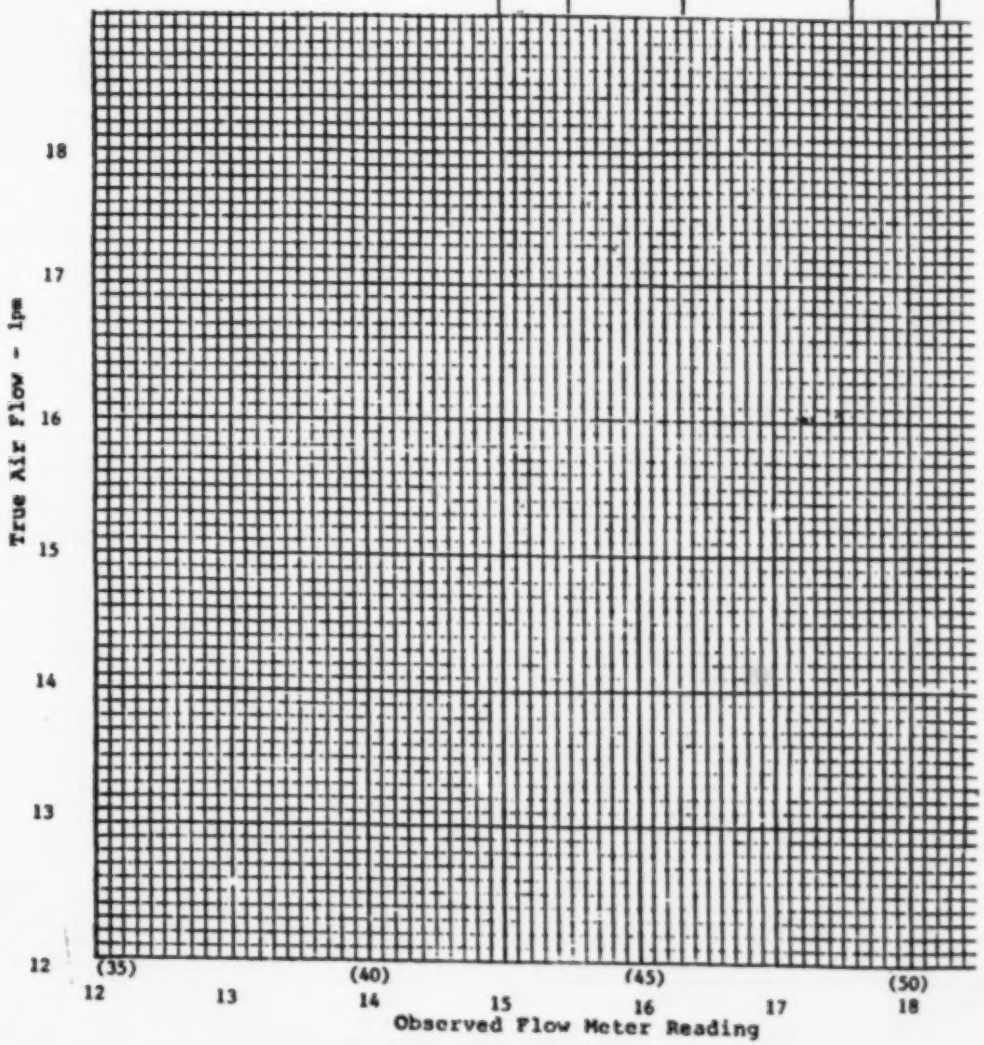

Figure 17a. Suggested Fine Flow Calibration Form

COARSE FLOW DICHOTOMOUS SAMPLER CALIBRATION Site:_____ Date:_____

DICHOT.

Ser. No._____

Last. Calib._____

Curr. Temp._____

Current Press_____

By_____

CALIBRATOR TYPE_____

Ser. No._____

Last Calib._____

Temp._____

Atm. Press._____

Remarks:

	Dichot. Rotameter Indicated	603 Rotameter Indicated	Actual lpm
At Base			
At Inlet			

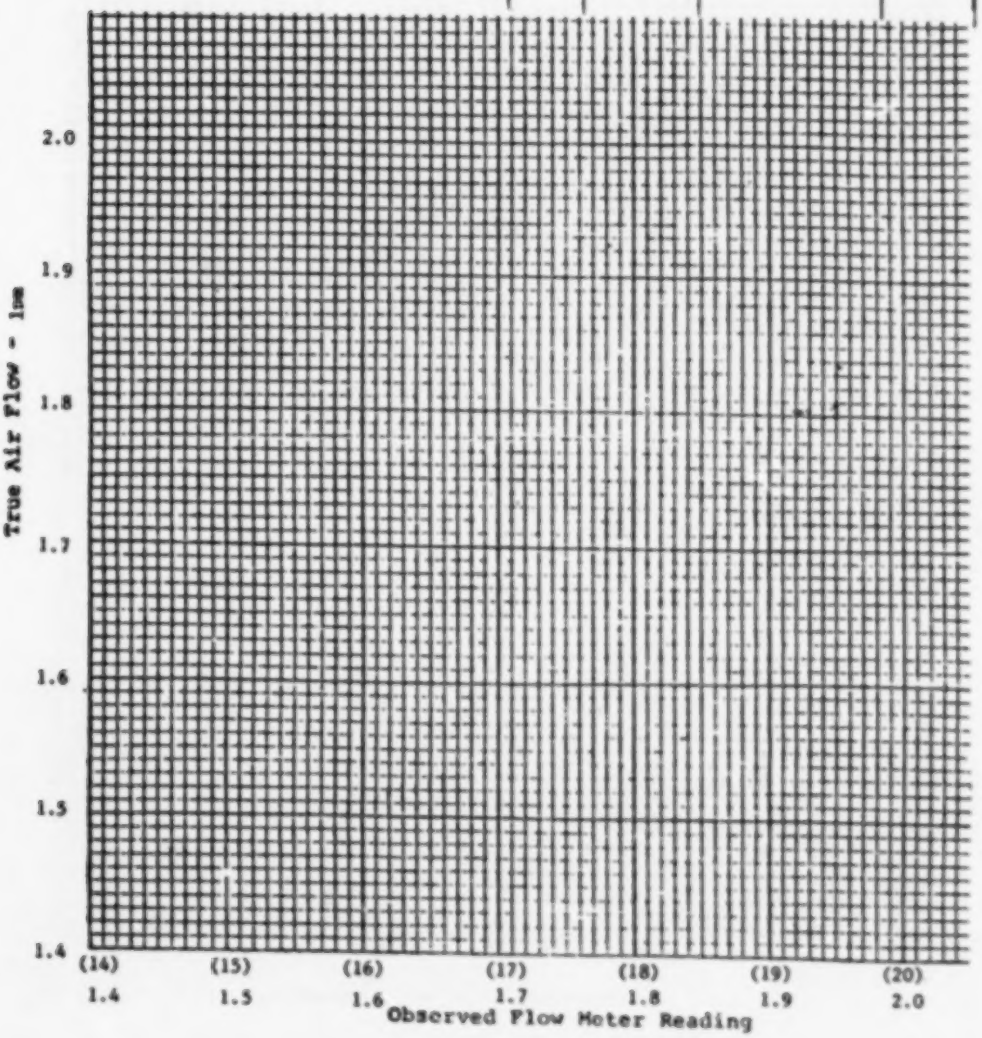

Figure 17b. Suggested Coarse Flow Calibration Form

Coarse Flow Calibration (Inlet)

This procedure is similar to the fine flow rotameter (inlet) calibration.

1. Attach the 603 rotameter to the valve of the inlet adaptor tube with the heavy wall vacuum tubing, making sure that the valve is fully open (counter-clockwise).

2. Insert and seal a clean set of filters (not filter #1) into the filter mechanism.

3. Turn the fine flow control valve (Figure 21) fully off (clockwise) so that only coarse flow is being drawn through the inlet.

4. Adjust the coarse flow control valve to read the 1.7 ℓpm set point which was determined at the base calibration. If the 603 rotameter does not give the same reading as it did during the base calibration, the seal mechanism is suspect of a leak and may need adjustment. (See Sec. 6.2.3-4 in Beckman's Manual).

5. If the same reading is found, proceed to adjust the valve to obtain two points above 1.7 ℓpm and two points below as before. Record these data on the fine flow calibration form in the "At Inlet" section [Figure 17(b)].

6. Again plot the points which should be similar to the "At Base" curve. From both curves determine the proper set point.

Total Coarse/Fine Flow Check Using Only the 604 Rotameter at the Sampler Inlet

After the complete calibrations for both the fine flow and coarse flow have been performed, a total flow check can be performed as follows:

1. Attach the 604 rotameter to the inlet adaptor and then to the inlet of the sampler as shown in Figure 15.

2. With a set of filters (not #1) clamped and sealed, and the pumps running, adjust the fine and coarse rotameters to the set points determined by the calibration.

3. Read the 604 rotameter and determine the total flow rate.

4. Next turn the coarse flow valve (fully clockwise) off. Observe the 604 rotameter reading as the fine flow. The difference between the total and fine flow rotameter reading should be the coarse flow. This flow check should be performed at the time of calibration and weekly, and the values recorded.

CALIBRATIONS USING A DRY TEST METER

By using a Singer Model DTM-115-3 dry test meter connected at the sampler inlet it is very easy to accurately set the fine and coarse flows. First, one closes both the fine and coarse flow valves to verify that both valves seat properly. Next, one opens the coarse flow valve and adjusts it so that the Singer gauge and a stopwatch indicate an inlet flow rate of 1.67 ℓpm. Since the fine flow is still shut, the inlet flow and coarse flow are the same. Now adjust the fine flow to 15 ℓpm, but do not adjust the coarse flow. A correct adjustment of the fine flow will result in a total inlet flow of 16.67 ℓpm as indicated by the Singer gauge and stopwatch. A simple test for leaks can also be made. The step-by-step instructions are as follows:

1. Connect the Singer dry test meter, as shown in Figure 18. Securely tighten the ferrule to prevent leaks in the calibration system.

The following leak test is only appropriate when the aerosol sampler is being set up or tested. During routine aerosol sampling, proceed directly to step 3.

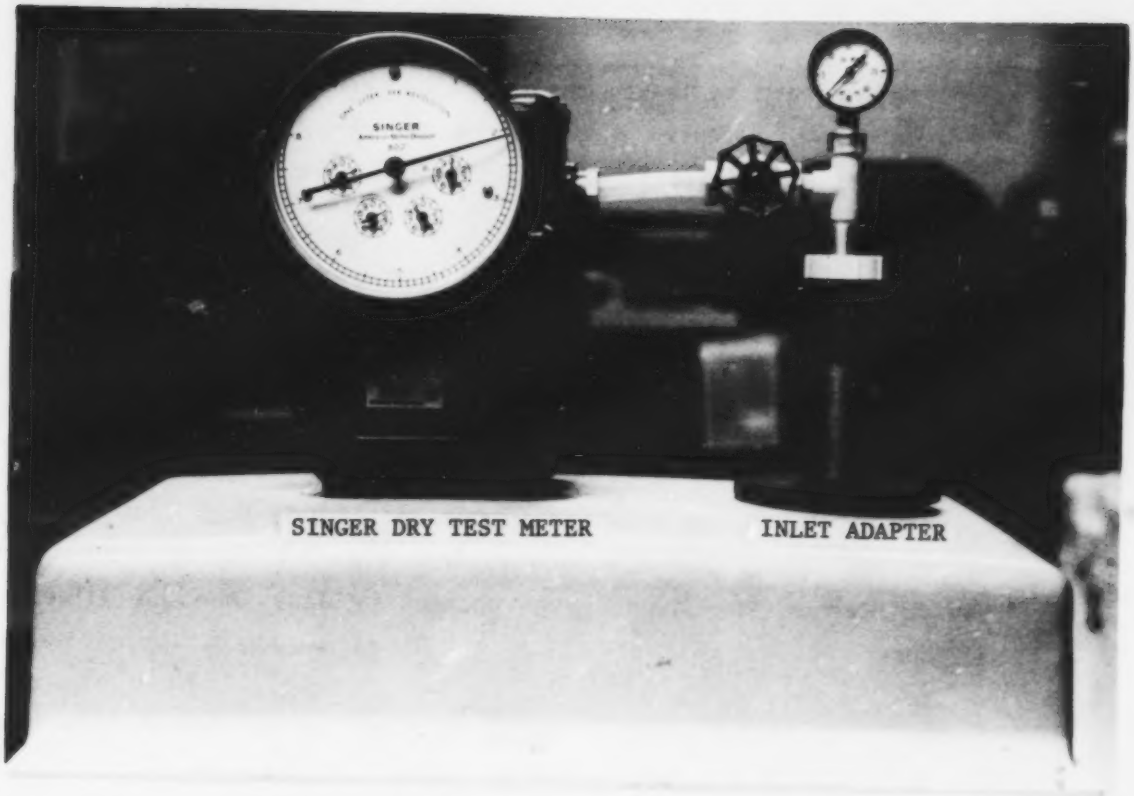

Figure 18. Typical Installation for Calibrations Using the Singer Dry Test Meter

2. a. While operating the sampler in the manual mode, insert a pair of filters, engage the filter seal, and turn on the pumps.

   b. Close the coarse particle flow valve on the dichotomous sampler.

   c. Close the valve at the sampler inlet shown in Figure 18.

   d. If there are no leaks, then the fine particle flow indicator on the dichotomous sampler should drop to zero, and the gauge at the sampler inlet (see Figure 18) should indicate a vacuum of at least 23 in. (58 cm) Hg.

   e. If there appears to be a leak, first verify that the ferrule, valve, etc, on the sampler inlet (see Figure 18) are not leaking. If the leak is traced to the sampler itself, then the sampler requires repair or adjustment.

3. Open the inlet valve shown in Figure 18. Close both fine and coarse valves and verify that the flow is less than 0.1 ℓpm by observing that the pointer on the Singer gauge changes by less than 0.1 liter in 60 seconds.

   Caution: To avoid possible damage to pumps do not operate the sampler for more than 20 min. with valve(s) closed.

4. Open the coarse particle flow valve, and as an initial approximation, set the coarse flow to 1.7 ℓpm using the instrument's rotameter as a flow indicator.

5. Measure the time for the Singer gauge pointer to change by at least 2 liters. For a coarse particle flow rate of 1.67 ℓpm, the time should be 72.0 seconds for 2 liters.

6. If the measured time deviates from 72.0 seconds by more than 1.0 second, adjust the coarse flow and measuring the time until a correct coarse particle flow rate is obtained.

   Verify the final value with an additional measurement

7. Now open the fine particle flow valve, and as an initial approximation, set the flow to 15 ℓpm using the instruments fine rotameter as a flow indicator.

8. Measure the time for the Singer gauge pointer to change 10 liters. Since a total flow of 16.67 ℓpm should be flowing into the inlet (15 fine plus 1.67 coarse), the stopwatch time should read 36.0 seconds.

9. If the measured time deviates from 36.0 seconds by more than 0.4 seconds, keep adjusting the fine flow and measuring the time until a correct total flow is obtained.

   Verify the final value with an additional measurement.

FILTER OVERLOAD SENSING SWITCH SETTING

The differential pressure switch which detects a filter overload condition is controlled by using the adjustment screw shown in Figure 14. This screw has been preset by the manufacturer and should not need resetting. However, it is recommended that the pressure differential setting be checked after completion of instrument calibration and prior to initiating a sampling program. This check should also be performed as part of the six-month flow audit described in Section 7, Quality Assurance.

Rotameter Method

To check the filter overload cutout setting, install the 604 rotameter and flow calibration adaptor. Turn off the coarse flow completely. The

instrument should be in the automatic mode. Begin to slowly turn the valve on the adapter tube clockwise. This will restrict the flow to the dichotomous sampler inlet. Note that as the flow is restricted, the sample will automatically compensate by increasing the flow to the normal value. Closely observe the 604 rotameter and note that at some point that the flow controller no longer can compensate for the restriction and the total flow will begin to decrease. Closely watch the 604 rotameter while continuing to restrict the flow with the valve. Eventually the cutout switch will cause the sampler to switch to another filter. It is at this cutoff point that the 604 rotameter reading should be recorded. Reset the sampler in the automatic mode on the same filter set. Repeat the above procedure a total of three times, recording the 604 rotameter reading each time that the cutoff switch switches the filters.

The filter overload pressure switch has been adjusted to actuate when the fine flow decreases from 15 ℓ/min to 14.25 ℓ/min by filter loading. If the check indicates a significant difference from this setting, the switch should be adjusted.

To do this, rotate center adjusting screw on switch (Figure 14) counter-clockwise to end of travel. Place instrument in automatic sampling mode and set fine flow at 15 ℓ/min. Restrict inlet flow using the calibration flow adaptor valve shown in Figure 15 until flow drops to 14.25 ℓpm, and then rotate the pressure switch adjusting screw clockwise until the filter pan is switched. Back the screw out ½ turn from this point. Contact Beckman if this method does not work.

Dry Test Meter Method

1. Perform steps 1 and 2 described in the above section, Calibrations Using a Singer Dry Test Meter.

2. Open the inlet flow valve shown in Figure 18.

3. Start sampling in the automatic mode.

4. Close the sampler's coarse particle flow valve.

5. Set the flow rate to 15 ℓpm as measured at the inlet. For this a 10 liters volume should pass through the dry test meter in 40 seconds.

To determine how the filter overload has been set previously, skip steps 6-8, and proceed directly to step 9 below.

6. Disable the filter overload switch by rotating its adjustment screw fully counter clockwise (see Figure 14) to end of travel.

7. Partially close the inlet flow rate restrictor so that the flow rate decreases by 7%. At this point the dry test meter should require 43 seconds to pass 10 liters. Note the vacuum reading: it should indicate about 5 to 10 in. (12 to 25 cm) Hg. This represents that the maximum pressure drop across a filter that will cause a 7% decrease in flow rate. If the vacuum is lower than the above range of values, then there is probably a leak in the flow system.

8. Slowly rotate the filter overload adjustment screw clockwise until the filters are caused to change.

9. Verify the setting of the filter overload adjustment screw. To do this first open the inlet flow restrictor valve. Then slowly close it so that the vacuum rises by about 1 in. (2.5 cm) Hg every 10 seconds. Verify that the filters are caused to change when the vacuum has the same value that was set in step 7 above.

SECTION 6

OPERATING PROCEDURES

It is recommended that the operator become familiar with the principles of operation (Section 2) and the instructions below before attempting to operate the instrument.

In testing the sampler or in learning how to operate it, it is unwise to use clean filters that have been preweighed for aerosol sampling. It is far better to use a pair of trays that are used only for practice or testing.

SAMPLER HOUSING

The dichotomous sampler is housed in a weather resistant shelter that must be firmly in place during sampling. The front door of the shelter may be removed by turning the keylock clockwise and pulling the door out and down. This will provide access to the keypad, printer, sample trays and flow controls. Maintenance and troubleshooting may necessitate removal of the entire shelter. To do this, raise and remove the inlet standpipe from the shelter. Remove the metal screws around the base of the shelter, and lift the shelter up until it clears the instrument.

CAUTION: Remember that whenever the standpipe has been removed, a No. 7½ or 8 rubber stopper or other suitable device must be inserted in the top of the impactor to prevent dirt or foreign objects from entering.

FRONT PANEL CONTROLS

The controls for programming and operating the sampler are located on the front control panel (Figure 19). Their functions are described below:

1. POWER Switch: When button is depressed, power is applied to the instrument; pushbutton is illuminated when power is on.

2. PAPER ADVANCE Switch: Paper in the printer is advanced when this switch is depressed.

3. KEYPAD: The keypad controls all instrument functions for programming and operation.

4. STATUS Lights: 8 light emitting diodes (LED's) which indicate the operational mode of the instrument, and identify malfunctions.

5. INSTRUCTION Lights: 8 light emitting diodes (LED's) which help the operator set up the instrument.

6. MANUAL CONTROL Switches:

   MANUAL OFF-ON (far left switch): When ON, permits use of 4 remaining switches (below) to test operation manually.

   SHUTTLE MOTOR (second switch from left): When depressed, this switch will drive the shuttle mechanism motor.

   SEAL MOTOR (Middle switch): When depressed, will drive the filter seal motor.

   PUMP MOTOR (second switch from right): When on, will provide power to both the fine and coarse flow pumps.

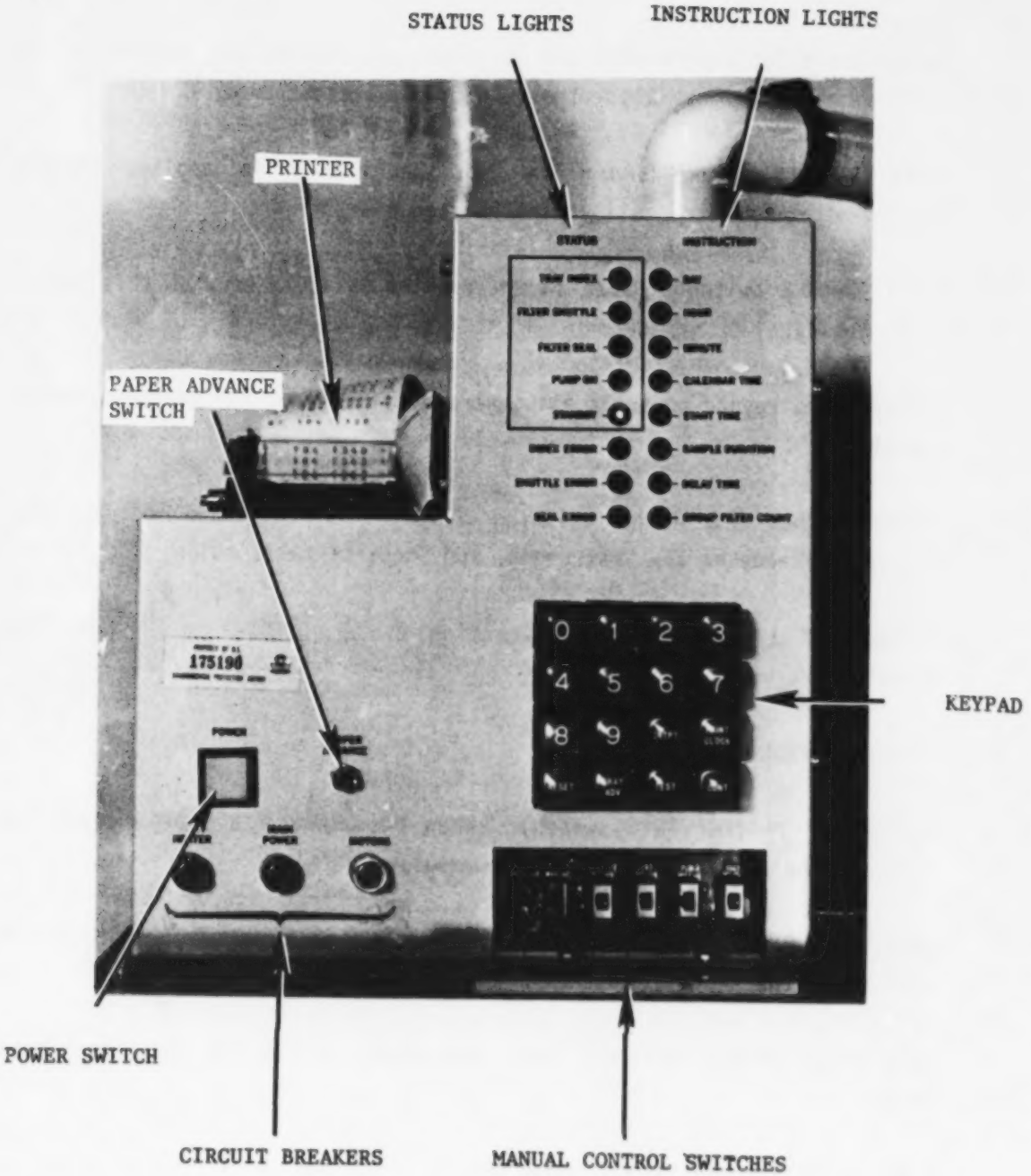

Figure 19. Sampler Front Panel Controls

TRAY MOTOR (far right switch): When depressed, will drive the tray indexing motor.

7. HEATER, MAIN POWER and MOTORS Circuit Breakers: Individual circuit breakers are provided for the following: main power, heater and electric motors. They trip and remove AC power from the equipment when an overload exists. To reset, turn the POWER switch off and momentarily push in on the tripped circuit breaker switch. Turn the POWER switch back on and make sure it is operating properly. If a circuit breaker trips again, do not reset. This is an indication that further repairs are needed.

INTERIOR FLOW CONTROLS

The dichotomous sampler is equipped with a flow meter and flow control valve for each of the fine and coarse flow circuits, as shown in Figure 20. The larger flow meter and its valve control the fine flow. This flow is nominally set at 15 ℓpm and then carefully set with an accurate flow calibrator. The coarse flow (smaller flow meter) is then set at 1.7 ℓpm.

As described in Section 5 of this report, a vacuum pressure gauge should be installed to provide additional flow measurements.

OPERATING INSTRUCTIONS

This section provides detailed, step-by-step instructions for programming and operating the dichotomous sampler. An example of a typical sampling program is given along the right-hand edge of the instructions to assist in relating sampling requirements to instrument instructions. A simplified summary of these instructions is given at the end of this section for use as a guide once the operator is familiar with the instrument.

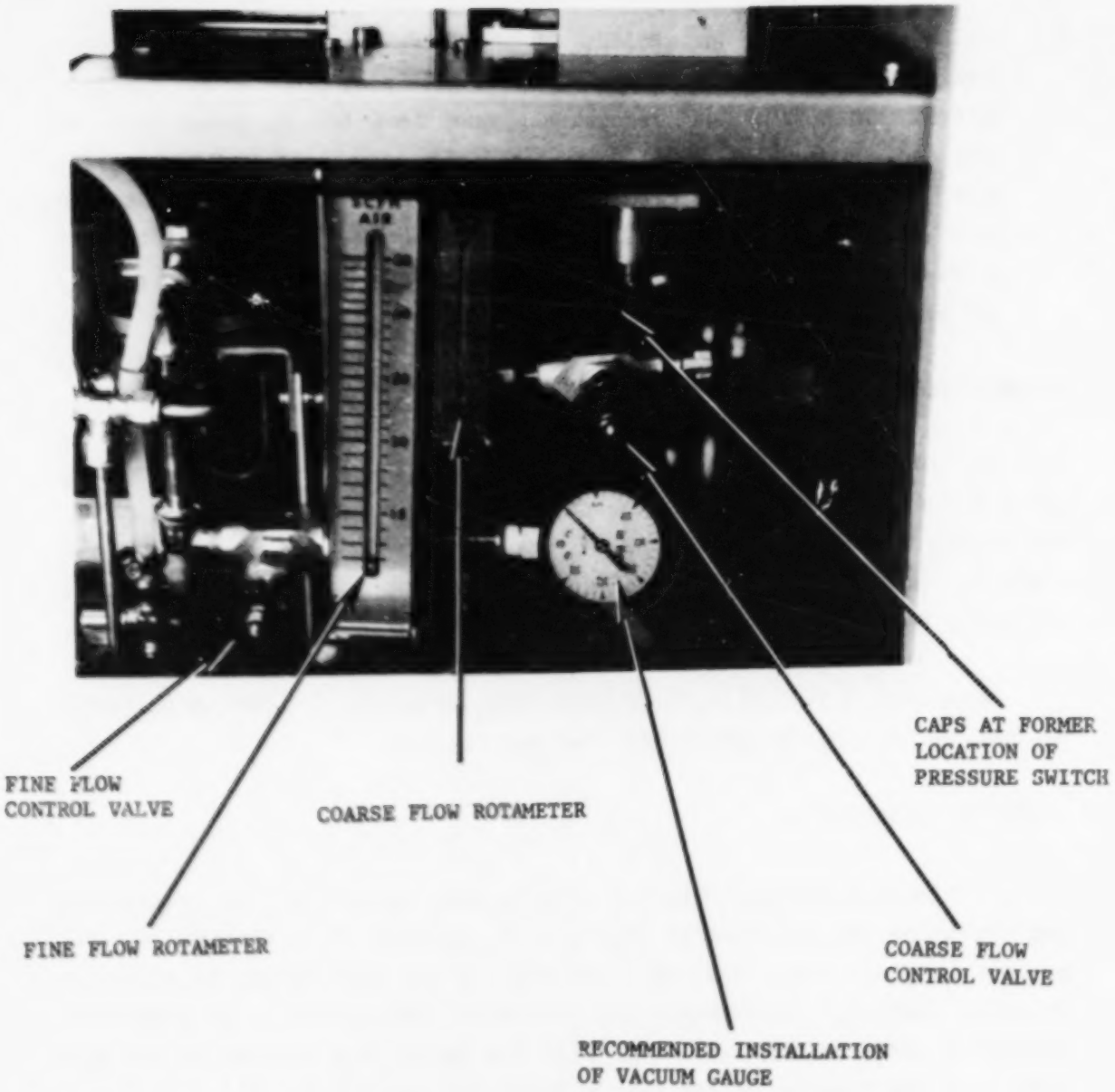

Figure 20. Interior Flow Controls, Showing Recommended Installation of Vacuum Gauge

OPERATION	INSTRUCTION	EXPLANATION/EXAMPLE
1. Record Keeping System	Enter appropriate information for logs or record keeping system to insure that necessary data for sample collection is properly supplied and recorded.	
2. Turn On	Plug instrument in and depress power switch. Immediately, power switch should light, printer should advance paper approximately 2", and pump should run momentarily. Instruction LED's (light emitting diodes), CALENDAR TIME and DAY should light.	
3. Set Calendar Date	Key in on the keyboard a 3-digit number -- 001 through 365 -- corresponding to the present date. Refer to Figure 21 for date and corresponding Julian Day to be used. DAY will turn off, and HOUR will light. CAUTION: Operator should note whether current year is a leap year, i.e., 1980, 1984, etc., and use the appropriate Julian calendar in Figure 21. The sampler is designed to print Day #1 after Day #365. The operator must adjust the dates on the printed record when sampling at the end of a leap year. See Figure 21, Part B (Leap Year Julian Calendar) for more detailed instructions.	Assume today's date is March 10, 1980. This is a leap year, so look up March 10 on leap year calendar. Corresponding Julian Day is 70. Key in 070.
4. Set Calendar Time	Key in a 2-digit number -- 00 through 23 -- corresponding to the present hour. HOUR will turn off, and MINUTE will light. Key in a 2-digit number -- 00 through 59 -- corresponding to the present minute. MINUTE will turn off, and printer will print out the present calendar date and time.	Assume time at the moment is 3:23 pm. Key in 15 for HOUR and 23 for minutes. Printout will be as follows: #1 DAY 070 HOUR 15 MINUTE 23

OPERATION	INSTRUCTION	EXPLANATION/EXAMPLE
	Following this printout, the filter shuttle will automatically retract, and the filter seal mechanism will open. The tray INDEX ERROR may then light.	
5. Filter trays	The filters are notched in one corner to insure correct positioning and sealing. As shown in Figure 8, the proper orientation of the filters is with the notched corner facing the impactor assembly and away from the front of the instrument. Also, note that the fine filter tray is closer to the front of the sampler and the coarse filter tray is to the rear. Raise the filter tray carriage to its uppermost position using the carriage release knob, and insert both trays. Tighten the filter carriage guide bar across the top of the filter trays. Make sure the trays fit squarely in the tray holders and against the small metal tabs in the corner of the tray holders (See Figure 8).	
6. Tray Position	Once the trays are loaded, lower the entire assembly completely. Depress RESET for approximately one second. If trays are positioned and seated properly, the INDEX ERROR light will go out, and START TIME and DAY will light. Depress TRAY ADV and a two digit number (02 to 36) of the desired filter for the start of sampling. The first pair of filters must always be kept unexposed as a blank.	Assume that sampling is to begin at tray position 3. Depress TRAY ADV and key in 03.
7. Sampling Start Date	Key in a 3-digit number -- 001 through 365 -- for the desired starting date of the sample. Refer to correct Julian calendar (Figure 21). DAY will turn off, and HOUR will light.	Assume the desired date for sample collection to start is March 15, 1980. Julian day is 075. Key is 075.

JULIAN CALENDAR SHOWING DATE AND CORRESPONDING JULIAN DAY FOR NON-LEAP YEAR

NOTE: CALENDAR ONLY SHOWS EVERY OTHER DAY

Jan.	1	1	Feb.	16	47	Apr.	3	93	May	19	139	July	4	185	Aug.	19	231	Oct.	4	277	Nov.	19	323
Jan.	3	3	Feb.	18	49	Apr.	5	95	May	21	141	July	6	187	Aug.	21	233	Oct.	6	279	Nov.	21	325
Jan.	5	5	Feb.	20	51	Apr.	7	97	May	23	143	July	8	189	Aug.	23	235	Oct.	8	281	Nov.	23	327
Jan.	7	7	Feb.	22	53	Apr.	9	99	May	25	145	July	10	191	Aug.	25	237	Oct.	10	283	Nov.	25	329
Jan.	9	9	Feb.	24	55	Apr.	11	101	May	27	147	July	12	193	Aug.	27	239	Oct.	12	285	Nov.	27	331
Jan.	11	11	Feb.	26	57	Apr.	13	103	May	29	149	July	14	195	Aug.	29	241	Oct.	14	287	Nov.	29	333
Jan.	13	13	Feb.	28	59	Apr.	15	105	May	31	151	July	16	197	Aug.	31	243	Oct.	16	289	Dec.	1	335
Jan.	15	15	Mar.	2	61	Apr.	17	107	June	2	153	July	18	199	Sept.	2	245	Oct.	18	291	Dec.	3	337
Jan.	17	17	Mar.	4	63	Apr.	19	109	June	4	155	July	20	201	Sept.	4	247	Oct.	20	293	Dec.	5	339
Jan.	19	19	Mar.	6	65	Apr.	21	111	June	6	157	July	22	203	Sept.	6	249	Oct.	22	295	Dec.	7	341
Jan.	21	21	Mar.	8	67	Apr.	23	113	June	8	159	July	24	205	Sept.	8	251	Oct.	24	297	Dec.	9	343
Jan.	23	23	Mar.	10	69	Apr.	25	115	June	10	161	July	26	207	Sept.	10	253	Oct.	26	299	Dec.	11	345
Jan.	25	25	Mar.	12	71	Apr.	27	117	June	12	163	July	28	209	Sept.	12	255	Oct.	28	301	Dec.	13	347
Jan.	27	27	Mar.	14	73	Apr.	29	119	June	14	165	July	30	211	Sept.	14	257	Oct.	30	303	Dec.	15	349
Jan.	29	29	Mar.	16	75	May	1	121	June	16	167	Aug.	1	213	Sept.	16	259	Nov.	1	305	Dec.	17	351
Jan.	31	31	Mar.	18	77	May	3	123	June	18	169	Aug.	3	215	Sept.	18	261	Nov.	3	307	Dec.	19	353
Feb.	2	33	Mar.	20	79	May	5	125	June	20	171	Aug.	5	217	Sept.	20	263	Nov.	5	309	Dec.	21	355
Feb.	4	35	Mar.	22	81	May	7	127	June	22	173	Aug.	7	219	Sept.	22	265	Nov.	7	311	Dec.	23	357
Feb.	6	37	Mar.	24	83	May	9	129	June	24	175	Aug.	9	221	Sept.	24	267	Nov.	9	313	Dec.	25	359
Feb.	8	39	Mar.	26	85	May	11	131	June	26	177	Aug.	11	223	Sept.	26	269	Nov.	11	315	Dec.	27	361
Feb.	10	41	Mar.	28	87	May	13	133	June	28	179	Aug.	13	225	Sept.	28	271	Nov.	13	317	Dec.	29	363
Feb.	12	43	Mar.	30	89	May	15	135	June	30	181	Aug.	15	227	Sept.	30	273	Nov.	15	319	Dec.	31	365
Feb.	14	45	Apr.	1	91	May	17	137	July	2	183	Aug.	17	229	Oct.	2	275	Nov.	17	321			

Figure 21a Julian Calendar for Non-Leap Year

JULIAN CALENDAR SHOWING DATE AND JULIAN DAY FOR LEAP YEAR (i.e., 1980, 1984, etc.)

NOTE: CALENDAR SHOWS ONLY EVERY OTHER DAY

Jan.	1	1	Feb.	16	47	Apr.	1	94	May	19	140	July	4	186	Aug.	19	232	Oct.	4	278	Nov.	19	324
Jan.	3	3	Feb.	18	49	Apr.	5	96	May	21	142	July	6	188	Aug.	21	234	Oct.	6	280	Nov.	21	326
Jan.	5	5	Feb.	20	51	Apr.	7	98	May	23	144	July	8	190	Aug.	23	236	Oct.	8	282	Nov.	23	328
Jan.	7	7	Feb.	22	53	Apr.	9	100	May	25	146	July	10	192	Aug.	25	238	Oct.	10	284	Nov.	25	330
Jan.	9	9	Feb.	24	55	Apr.	11	102	May	27	148	July	12	194	Aug.	27	240	Oct.	12	286	Nov.	27	332
Jan.	11	11	Feb.	26	57	Apr.	13	104	May	29	150	July	14	196	Aug.	29	242	Oct.	14	288	Nov.	29	334
Jan.	13	13	Feb.	28	59	Apr.	15	106	May	31	152	July	16	198	Aug.	31	244	Oct.	16	290	Dec.	1	336
Jan.	15	15	Mar.	2	62	Apr.	17	108	June	2	154	July	18	200	Sept.	2	246	Oct.	18	292	Dec.	3	338
Jan.	17	17	Mar.	4	64	Apr.	19	110	June	4	156	July	20	202	Sept.	4	248	Oct.	20	294	Dec.	5	340
Jan.	19	19	Mar.	6	66	Apr.	21	112	June	6	158	July	22	204	Sept.	6	250	Oct.	22	296	Dec.	7	342
Jan.	21	21	Mar.	8	68	Apr.	23	114	June	8	160	July	24	206	Sept.	8	252	Oct.	24	298	Dec.	9	344
Jan.	23	23	Mar.	10	70	Apr.	25	116	June	10	162	July	26	208	Sept.	10	254	Oct.	26	300	Dec.	11	346
Jan.	25	25	Mar.	12	72	Apr.	27	118	June	12	164	July	28	210	Sept.	12	256	Oct.	28	302	Dec.	13	348
Jan.	27	27	Mar.	14	74	Apr.	29	120	June	14	166	July	30	212	Sept.	14	258	Oct.	30	304	Dec.	15	350
Jan.	29	29	Mar.	16	76	May	1	122	June	16	168	Aug.	1	214	Sept.	16	260	Nov.	1	306	Dec.	17	352
Jan.	31	31	Mar.	18	78	May	3	124	June	18	170	Aug.	3	216	Sept.	18	262	Nov.	3	308	Dec.	19	354
Feb.	2	33	Mar.	20	80	May	5	126	June	20	172	Aug.	5	218	Sept.	20	264	Nov.	5	310	Dec.	21	356
Feb.	4	35	Mar.	22	82	May	7	128	June	22	174	Aug.	7	220	Sept.	22	266	Nov.	7	312	Dec.	23	358
Feb.	6	37	Mar.	24	84	May	9	130	June	24	176	Aug.	9	222	Sept.	24	268	Nov.	9	314	Dec.	25	360
Feb.	8	39	Mar.	26	86	May	11	132	June	26	178	Aug.	11	224	Sept.	26	270	Nov.	11	316	Dec.	27	362
Feb.	10	41	Mar.	28	88	May	13	134	June	28	180	Aug.	13	226	Sept.	28	272	Nov.	13	318	Dec.	29	364
Feb.	12	43	Mar.	30	90	May	15	136	June	30	182	Aug.	15	228	Sept.	30	274	Nov.	15	320	Dec.	31	366
Feb.	14	45	Apr.	1	92	May	17	138	July	2	184	Aug.	17	230	Oct.	2	276	Nov.	17	322			

Figure 21b. Julian Calendar for Leap Years

Note: The control system for the Beckman Sampler is designed to accept only Julian days up to 365. If sampling is to occur on Dec. 31 of a Leap Year (i.e.,day nr. 366 in 1980, 1984, etc.),the sampler will record this day as 001 of the following year. The operator must be aware of this and manually correct the printer output for day 366 and 001 and then at a convenient point after January 1, the printer can be set one day back to coincide with the normal non-leap year Julian Calendar.

OPERATION	INSTRUCTION	EXPLANATION/EXAMPLE
8. Set Sampling Start Time	Key in a 2-digit number -- 00 through 23 -- for the desired starting hour of of the sample. HOUR will light. Key in a 2-digit number -- 00 through 59 -- for the desired starting minute of the sample. START TIME and MINUTE will turn off, and SAMPLE DURATION and DAY will light.	Assume desired time for sample collection to start is 2:30 p.m. Key in 14 for HOUR aand 30 for MINUTE.
9. Set Sampling Duration Time	The following three operations will set the total time in days, hours and minutes that the pump will run for <u>each</u> sample collected.	
	A. Key in a 3-digit number -- 000 through 365 -- for the number of days (24-hour increments) over which each sample is to be collected. DAY will turn off and HOUR will light.	Assume desired duration of each collection is 30 hours. This is 1 day plus 6 additional hours. Key in 001 for DAY.
	B. Key in a 2-digit number -- 00 through 23 -- for number of additional hours over which sample is to be collected. HOUR will turn off, and MINUTE will light.	Key in 06 for 6 additional hours over first day.
	C. Key in a 2-digit number -- 00 through 59 -- for the number of minutes over which the sample is to be collected. MINUTE will turn off and DELAY TIME and DAY will light.	Key in 00 for minutes, as no additional minutes are desired for sample collection.
10. Set Filter Delay Time	The following three operations will set the total time in days, hours and minutes between each sample collection. This <u>time is always measured from the beginning, or start time, of one group of filters to the beginning, or start time, of the next group</u>, and is called the Delay Time.	

OPERATION	INSTRUCTION	EXPLANATION/EXAMPLE
10. Cont.- Set Filter Delay Time	A. Key in a 3-digit number -- 000 through 364 -- for the desired number of days of delay between the sampling start of each group of filters. DAY will turn off, and HOUR will light. Still using our example, Start Time was set for 2:30 p.m. on March 15. Six days from March 15 means automatic sampling will begin again on March 21 at 2:30 p.m. Key in 006 for filter group delay time of six days from beginning of sample to beginning of next sample.	Assume sample collection is desired every six days. This means six days from the last group of filters to the start time of the next set of filters.
	B. Key in a 2-digit number -- 00 through 23 -- for the desired number of hours of additional time delay between the sampling start of each group of filters. HOUR will turn off, and MINUTE will light.	Since no additional hours are desired over and above the six day delay time, key in 00.
	C. Key in a 2-digit number -- 00 through 59 -- for the desired number of minutes of additional time delay between the sampling start of each group of filters. MINUTE will turn off, and GROUP FILTER COUNT will light. NOTE: If a delay time of 000 days, 00 hours and 00 minutes is keyed in, the instrument will automatically switch into a continuous mode, sampling consecutively through all 35 filter pairs.	Since no additional minutes are desired over and above the six day delay time, key in 00.

OPERATION	INSTRUCTION	EXPLANATION/EXAMPLE
11. Set Filters per Group Number	Key in a 2-digit number -- 00 through 36 -- for the desired number of filter pairs to be sampled at each sampling time. Note that each sample actually involves collection for a filter pair, one coarse and one fine.	Assume 2 filter pairs are desired for each collection, 2 fine and 2 coarse. Since our sampling duration has been set at 30 hours, sampling time for for each filter pair will be 30 hours. Key in 02 for 2 filter pairs per group.
		DAY HOUR MIN DATE #2 075 14 30 START TIME #3 001 06 00 SAMPLING TIME #4 006 00 00 DELAY TIME #5 02 FILTER PAIR per GROUP
12. Verify Calendar Time vs. Start Time	Push CLOCK PRINT key to verify that the selected Start Date/Time is later than the Calendar Time. If the Start Time is earlier than the Calendar Time, go back to operation #6, and proceed again. Leave all INSTRUCTION LED's off and STAND BY on. The instrument will automatically wait for the Calendar Time to coincide wth the Start Time, at which time sampling will begin automatically according to the programmed	Still using our example of today's date, being March 10, 1980, or 070 on the leap year Julian Calendar. Assume Start Date/Time had mistakenly been entered as March 5, 1980, or 065 on the leap year Julian calendar. Lower tray, depress RESET. Depress TRAY ADV, key in starting position and re-enter correct Start Date, which is 075, and remaining data in Steps #2 through #5.

SIMPLIFIED OPERATING INSTRUCTIONS

1.	RECORD KEEPING -	Enter appropriate data on all required record keeping forms.
2.	TURN ON -	Plug in instrument and turn on power switch.
3.	SET CALENDAR DATE AND TIME -	Key in a three-digit DATE number - 000 through 365, a two-digit HOUR number - 00 through 23, and a two-digit MINUTE number - 00 through 59 - corresponding to present date and time. Refer to appropriate Julian Calendar for DATE entry.
4.	LOAD FILTER TRAYS -	Properly insert filter trays. Lower trays completely. Press RESET for one second.
5.	TRAY ADV -	Press TRAY ADV to advance tray to filter pair desired (not first pair).
6.	SET SAMPLING START DATE AND TIME	Key in a three-digit DATE number - 000 through 365, a two-digit HOUR number - 00 through 23, and a two-digit MINUTE number - 00 through 59, for desired sampling start date and time. Refer to appropriate Julian Calendar for DATE entry.
7.	SET SAMPLING DURATION TIME	Key in a three-digit number - 000 through 365, a two-digit number - 00 through 23, and a two-digit number - 00 through 59, for the total number of days, hours and minutes of sampling duration for each sample collected.

8. SET FILTER DELAY TIME — Key in a three-digit number - 000 through 365, a two-digit number - 00 through 23, and a two-digit number - 00 through 59, for the total number of days, hours and minutes of desired delay time between the sampling start of each filter group. Inputs of zero days, hours and minutes automatically initiate the continuous sampling mode.

9. SET FILTERS PER GROUP NUMBER - Key in a two-digit number - 00 through 36 for the number of filter pairs to be sampled at each sampling time. If zero delay time is selected in Step 7, the Filters per Group number is 00.

Following Step #9 (or #8 if delay time is 000 00 00), printer will automatically print out data which has been entered as follows:

	(DAY)	(HOUR)	(MIN)	
#2	XXX	XX	XX	(Start Time/Date)
#3	XXX	XX	XX	(Sampling Time)
#4	XXX	XX	XX	(Delay Time)
#5			XX	(Filters per Group)

9. VERIFY CALENDAR TIME VS. START TIME - Depress PRINT CLOCK key to see if Start Date/Time are later than Calendar Date/Time. If not correct, push RESET and repeat Steps 4-7.

STAND-BY will light, indicating sampler is in a "wait" mode and will automatically begin sampling when Calendar Date/Time Reaches Start Date/Time.

SAMPLER OPERATION

Once the operating instructions have been entered into the instrument's microprocessor, the sampler's clock runs until the preselected sample date/time is reached. At that point the sampler starts automatic control. The initial setup data are printed, followed by the shuttle mechanism inserting a filter pair, the seal mechanisms closing, and the flow pump turning on. Filter number and pumping start time are printed automatically.

Modes of Operation

The dichotomous sampler can be programmed for one of two operating modes: Group Mode or Continuous Mode. Group Mode is selected with the sampling program calls for one or more samples to be collected and then for some interval to pass before another sample or group of samples is collected. For example, this mode would be used to collect a 24-hour sample every sixth day. The instrument would be programmed with a FILTER GROUP COUNT of 1, a SAMPLING TIME of 1 day, and a GROUP DELAY TIME of 6 days. Similarly, if you wanted to collect a group of three samples every 30 days, the FILTER GROUP COUNT would be 3, SAMPLING TIME of 1 day, and a GROUP DELAY TIME of 30 days. Note that the DELAY TIME is the time between the start of each filter group, not the time between the completion of one group and the start of the next. Following completion of the last sample of each group, the filter pair will be returned to the tray and the instrument will go to STANDBY until completion of the remainder of the GROUP DELAY TIME.

Although the Group Mode is considered the normal operating mode, the instrument can run in the Continuous Mode as well. This mode is automatically selected if the GROUP DELAY TIME is set at zero during initial setup. In this mode the sampler will sequence through all 35 available filter pairs, pumping for the preselected SAMPLE TIME for each pair, and automatically changing to the next unexposed filter pair as soon as the SAMPLE TIME is completed.

There is a disadvantage in using the Continuous Mode. In this mode the 25 seconds needed to change filters are not included in any of the selectable time intervals, which will cause the start times for a sequence of filters to lag increasingly. If one wants to sample continuously, on a fixed schedule, then use the Group Mode, and set the sampling time to be 1 minute less than the desired time between filter changes. The following are some examples:

Example 1: Continuous sampling with filter changes every midnight starting on day 160.

Day	Hour	Minute	
160	00	00	Start Time
000	23	59	Sampling Time
001	00	00	Delay Time
		01	Filters per group

Example 2: Continuous sampling with filter changes at 7:00 a.m. and 7:00 p.m. starting on day 80:

Day	Hour	Minute	
080	07	00	Start Time
000	11	59	Sampling Time
000	12	00	Delay Time
		01	Filters per group

Filter Overload

The pump will continue to run for the programmed sampling duration unless a filter overload occurs. This is determined by the differential pressure switch. If the fine particulate flow rate drops by more than .75 ℓ/min (5% of the normal flow rate of 15 ℓpm), a signal from the switch terminates the pumping cycle. The filter pair is returned to the tray, and the calendar date/time is printed on the printing tape. A symbol "Δ" is also printed to identify the overload (refer to Figure 22). The next filter pair is inserted, and pumping resumes. The pumping time for this second set of filters will be

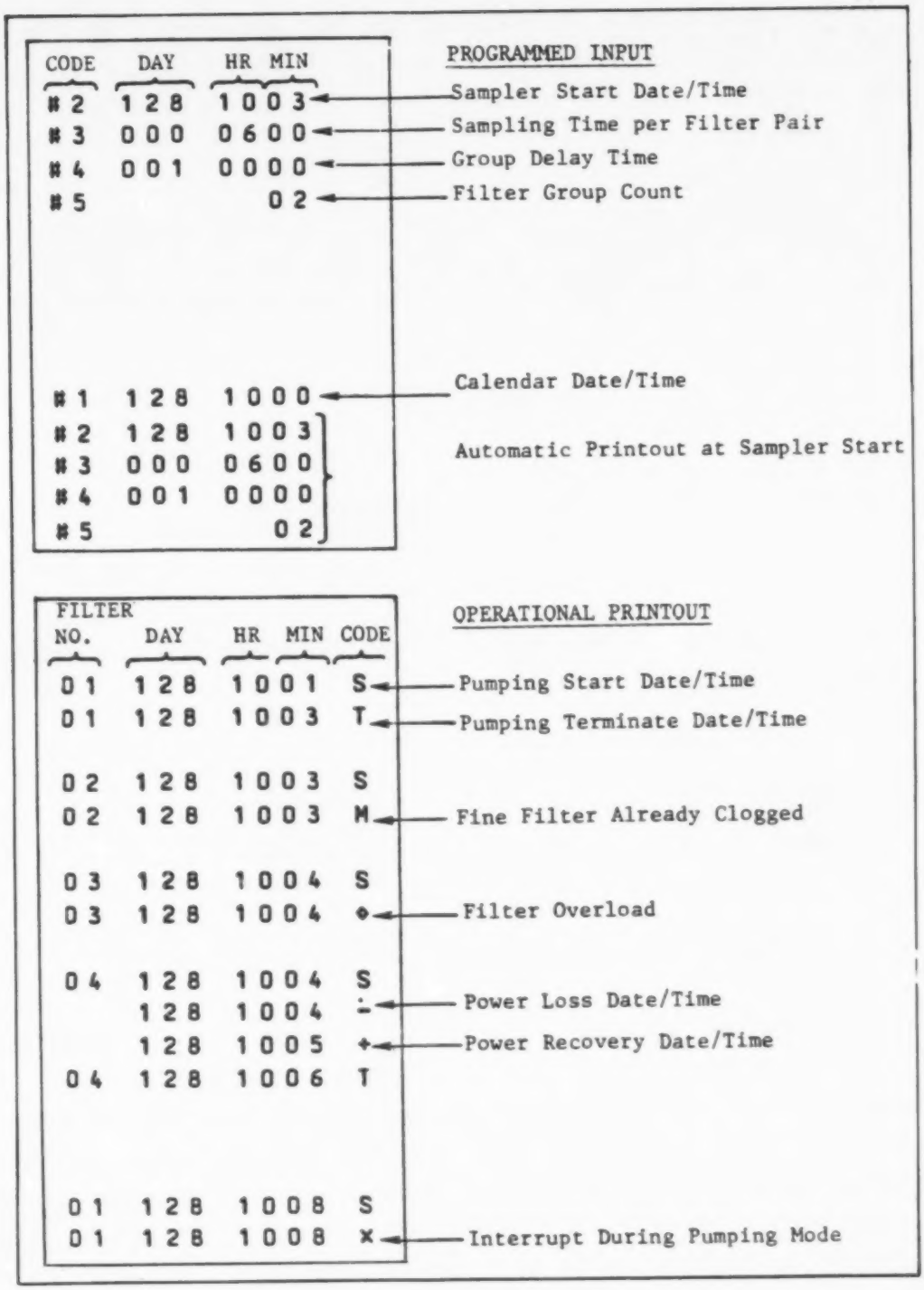

Figure 22. Example of Printer Printout Showing Programmed Input Instructions and Operational Outputs

the balance of the programmed sampling time. The sampling time will not include the time necessary to switch filters, which is only about 25 seconds.

If a second overload occurs before the end of the sampling duration, the filters will again recycle. Pumping time on the third set of filters will be the time remaining in the programmed sampling time.

If an overload occurs during Group Mode operation, the filters are recycled, and the follow-on filter pair is counted as one sample of the filter group count.

Interrupt Procedure

The interrupt sequence allows the operator to interrupt a pumping cycle, change filter trays, and/or preselect filter, and then to continue sampling with the existing instructions intact. See INTPT key operation description below.

Power Failure

In the event of a power failure, a battery will continue to supply power to the microprocessor, and the system wil continue in the same mode and sequence as before loss of power. NOTE: The battery has a capacity of 30 minutes; if power is off for a longer period, the sampler instructions will have to be reset once power is restored.

When all lights are off, the filter trays may be changed, since the carriage assembly will automatically reset at Filter #1. Once the new tray is inserted, the sampler will continue with Filter #1 if the CONT key is pushed. Since Filter #1 must always be left unexposed, do not press CONT. Instead, depress the TRAY ADV key followed by any two-digit number 02 through 36 for the filter number that sampling is to continue on. The tray will advance to the selected filter. When the tray stops, press the CONT key, and sampling will continue in the original timing sequence.

The pumping on the first filter after the interrupt cycle is the balance of the initial pumping interval. The interrupt sequence is noted by the symbol "X" on the printer output. Figure 23 shows a typical interrupt timing cycle.

Printer Output Format

The printer tape provides the sampler test history for each sample cycle. Data for each printout consists of a code number or filter number, date/time data, and sampler function designator. Figure 22 shows a typical printout.

KEYPAD OPERATION

INTPT (Interrupt) Key

INTPT key interrupts the sampler during automatic cycling and forces the program into a "wait" mode. The key is not active during the automatic sampler operation. Depressing the key does not affect initial input program data. Instrument operation following actuation of the INTPT key depends on the operating mode at the time the key is depressed.

Actually, the INTPT key during sampling terminates the sampling mode, recycles the filters to the tray, and puts the sampler in a "wait" mode.

Actuating the INTPT key during the filter insertion cycle or during the seal closure cycle results in a 5-second pumping time followed by the seal opening and recylcing filters to the tray. The designator "X" and calendar date/time information are printed at completion of the pumping cycle. Actuating the INTPT switch during the seal opening cycle or during the shuttle return cycle forces the instrument into the "wait" mode after the filters are recycled to the tray. "X" designator is not printed.

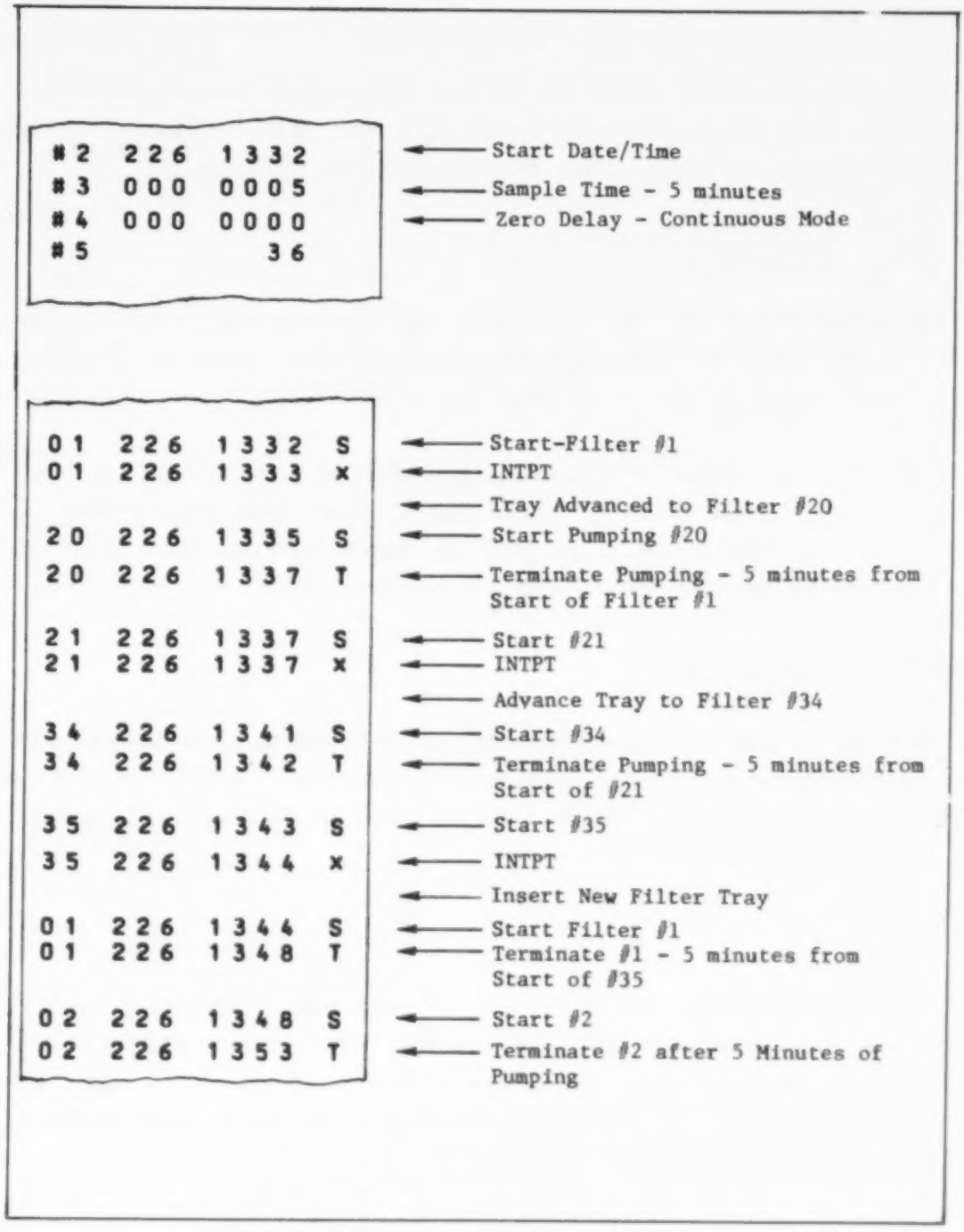

Figure 23. Typical Printer Output for Interrupt Cycle

PRINT CLOCK Key

Depressing the PRINT CLOCK key prints the current calendar date/time information. This key is disabled only during printer operation and is active at all other times. A typical clock printout is shown in Figure 23.

RESET Key

Depressing the RESET key terminates the sampling mode, recycles the filters to the tray, and resets all input program data. RESET key is active at all times after initially entering the calendar date/time information.

Resetting the sampler will cause a TRAY INDEX error signal if the RESET key is actuated while sampling filter pairs other than Pair Number 1. Following filter recycle the trays must be lowered to position 1 and, the RESET key must be depressed before entering operating data.

TRAY ADV (Tray Advance) Key

This key is used in conjunction with the INTPT key to allow selection of a specific filter pair for the next sampling position. NOTE: The key is active only if the calendar time is set, the trays are in position 1, and the tray index error light is off.

TEST Key

The TEST Key selects the instrument self-test mode. Depressing the TEST key followed by a numerical key selects a specific self-test routine. This key is active only at power on, before entering calendar clock data, and following the completion of sample Pair Number 36. The key is inactive during sampler operation.

CONT (Continue) Key

This key restarts sampler operation under the initial timing parameters. The key is active only after depressing the INPT key and following sample completion of filter Pair Number 36.

SECTION 7

QUALITY ASSURANCE

Throughout this report are instructions, recommendations, and cautionary notes which will greatly improve the quality of data produced, if they are followed carefully. In addition, the checks and audits prescribed below should be incorporated into the operator's quality control program.

NOTE: The weekly flow check and six-month flow audit can be performed using suitable calibrated rotameters, limited orifice, dry test meters, or similar flow measuring devices. The instructions below are for use with the 604 and 603 rotamters, but similar procedures would be followed in using the other instruments.

Weekly Flow Check

During periods of routine operation, the flow should be checked and set as follows on a weekly basis. Note: flow checks should be made during normal sampling operations.

1. Place the 604 rotameter and adaptor assembly on the inlet of the sampler. Measure and record the total flow. Also record both the fine and coarse rotameter settings and the vacuum gauge reading.

2. With the 604 rotameter in place, turn the coarse flow off. Record the 604 rotameter and fine rotameter readings.

3. Turn the coarse flow back on, and adjust it to the proper set point determined from the most recent calibration.

4. Adjust the fine flow to the proper set point determined from the most recent calibrations.

5. Again read the 604 rotameter for total flow. If the total flow differs by more than 0.25 ℓpm from 16.7 ℓpm, adjust the fine flow until the proper reading is obtained on the 604 rotameter. Make sure that the coarse flow rotameter is still at its proper set point.

6. Record total flow and vacuum gauge readings after final adjustments have been made. Figure 24 shows a typical data log form for use in weekly checks.

Weekly Tape Check

During the weekly flow checks described above, the operator should check the printer output to see that the information shown matches the programmed instructions. The results of this check should also be recorded, using the form shown in Figure 24 or other suitable log.

Six-month Flow Audit

Every six months the coarse, fine, and total flows of the dichotomous sampler must be checked with an independent calibration system using the procedure below. The filter overload cutout switch setting should be checked at the same time. A 604 and 603 rotameter adaptor tube assembly other than the units normally used for routine calibration purposes, or some other type of independent calibration equipment, should be used. All audit results must be recorded on an audit log. One copy is kept on file at the site, and one is returned to the agency which processes the audit results. Figure 25 shows a typical form for recording this audit information.

AUTOMATIC DICHOTOMOUS SAMPLER

WEEKLY LOG

City_____
EPA Site No._____
EPA Serial No._____
Instrument Mfr._____
Inst. Model No._____
Inst. Serial No._____
Date of Last
Calibration
Sample Time
Setting _____
Delay Time _____
Group Filter Count_____
Last Cleaning (Date)_____

AT LAST CALIBRATION: (AT INLET)

CUTOFF SWITCH SET AT (L/M)_____

Coarse pts.		Fine pts.		(604) Total pts.	
Roto	Flow	Roto	FLow	Roto	Flow

Total/Fine
Calib 604
Ser. No._____
Last Calib._____
Atm. Press_____
By_____

Course
Calib 603
Ser. No._____
Last Calib._____
Atm. Press_____
By_____

Coarse Tray No._____ Fine Tray No._____Tray Type_____

Start Date (Julian Day)_____
Start Date (Mo/Da/Yr)_____
Start Hour_____
Fine Flow (Roto/Flow)_____
Coarse Flow (Roto/Flow)_____
Total Flow (Coarse + Fine)_____
Coarse Sample I.D. No._____
Fine Sample I.D. No._____
Duration of Run (Hrs, Min, Sec)_____
Coarse Sample I.D. No._____
Fine Sample I.D. No._____
Duration of Run (Hrs, Min, Sec)_____
Sample Time and Date Checked
Against Tape? (Date + Time)_____
Operator's Initials_____Date_____

Wkly Flow Check With 604

	BFR adj.	AFT adj.
Tot. flow	_____L/M	_____L/M
Fine flow	_____L/M	_____L/M
Diff.	_____L/M	_____L/M
(coarse)	_____	_____
VAC.	_____	_____

COMMENTS:

Figure 24 Suggested Weekly Log Form

DICHOTOMOUS SAMPLE FLOW RATE AUDIT
Type of Sampler _____

	Dichot.	Audit Calibrators Total/Fine Calib. 604	Coarse Calib. 603
AGENCY _____	SER. NO. _____	SER. NO. _____	SER. NO. _____
CITY _____	LAST CALIB. ____	LAST CALIB. _____	LAST CALIB. _____
SITE # _____	CURR. TEMP. ____	TEMP. _____	TEMP. _____
DATE _____	CURR. PRESS. ____	ATM. PRESS. _____	ATM. PRESS. _____
AUDITOR _____	BY _____	BY _____	BY _____

ROTAMETERS USED AT LAST CALIB.: SERIAL # 604 _____ # 603 _____

All tests to be performed through filters at inlet on a normal sampling day.

	Audit Calib. Readings		Dichot. Readings		Percent Difference
1.	Total Flow: 604 Roto =		Fine Roto =		
			Coarse Roto =		
			Total Flow		
	Coarse Off: 604 Roto =		Coarse Off: Fine Roto =		
	Difference:				
2.	Fine Flow: 604 Roto Settings	Flow L/Min.	Fine Roto	Flow L/Min.	Difference
3.	Coarse Flow: 603 Roto Settings		Coarse Roto		
4.	604 roto: ___,___,___		Cut off switch set at (L/M)		

The following information pertains to the sample which was present on the monitor during this particular QC inspection:

	STATION OPERATOR	QC INSPECTOR
DATE OF SAMPLE		
STARTING TIME (MIN.)		
ENDING TIME (MIN.)		

COMMENTS:

Figure 25 Suggested Flow Rate Audit Form

1. Total flow: Place the audit inlet adapter, with the valve fully open (counterclockwise) and the 604 Rotameter attached onto the inlet of the dichotomous sampler impactor. Tighten the hose clamp and proceed as follows:

   a. First, measure the total flow as indicated by the 604 rotameter and log it on the form. Log the dichotomous fine flow rotameter and coarse flow rotameter readings and their corresponding flows that the sampler is currently operating at as determined by your last calibration.

   b. Next, turn the coarse flow fully off and log the 604 rotameter reading and the fine flow rotameter reading.

2. Fine flow: With the coarse flow off, set the fine flow to read each of the four 604 rotameter set points as noted on the audit form. Log both the fine flow rotameter readings and the fine flow in ℓ/min as determined by the last calibration for each of the 604 rotameter audit set points.

3. Coarse flow: Next, reset the coarse flow rotameter to its normal set point and turn the fine flow completely off. Replace the 604 audit rotameter with the 603 audit rotameter and proceed to check each of the 4 audit set points. Log the 603 rotameter readings and the coarse flow rotameter values and their corresponding flows as determined by the last calibrations.

Filter Overload Cutout Switch Check

Once the six month flow audit has been completed, the filter overload cutout switch setting should be checked. Refer to the instruction for this check in Section 5, Checkout and Calibration.

Finally, return the sampler to its normal operation setting. Void the filter set that was running on the day of the audit and program the unit to

run on the next scheduled sampling day. Within one week after this audit is performed, the impactor head assembly should be removed and cleaned in accordance with the procedure described in Section 8 of this manual.

Six-Month Control Check

Every six months control checks must be peformed on at least 5% of the data being collected. The checks must compare the data obtained from the computer output to the raw data recorded on the weekly logs. Coarse, fine, and total mass calculations must be confirmed from raw data.

SECTION 8

MAINTENANCE

SCHEDULE FOR ROUTINE MAINTENANCE

On a yearly basis (or after every 180 24-hour days of operation), the operator should perform the following maintenance:

1. Replace the Thomas pump diaphrams.

2. Inspect and replace if necessary the shock mounts on the Thomas pump.

3. Clean the exhaust filters on the Thomas pump.

4. Lubricate the lock assembly on the front access door.

5. Replace the inlet tube connector.

Every six months (or after every 90 24-hour days of operation), the operator should perform the following maintenance:

1. Clean the impactor assembly.

2. Clean the inlet tube and fractionating inlet.

3. Perform a multipoint flow calibration on the coarse and fine flow systems as described in Section 5 of this report.

MAINTENANCE INSTRUCTIONS -- YEARLY MAINTENANCE

1. In performing the suggested yearly maintenance, it is necessary to remove the entire sampler housing to provide access to the pumps and exhaust filters. Unplug the sampler power cord, and remove the 10 socket head cap screws which attach the housing to the instrument chassis. Remove the inlet tube, and carefully lift the housing straight up until it clears the instrument.

2. Diaphram Replacement:

   a. Remove the large fine flow accumulator canister located directly above the Thomas Pump.

   b. Disconnect the polyethylene vacuum tubing which is attached to the pump with a worm drive clamp.

   c. Remove the four screws in each diaphram head of the pump (eight in total).

   d. The diaphrams are visible once the pump heads have been lifted off the pump.

   e. Replace both diaphragms and reassemble the pump.

3. Shock Mount Inspection: After replacing the pump diaphragms, thoroughly inspect the shock mounts for cracks, torn surfaces, or other signs of fatigue. Replace the mounts, if necessary.

4. Exhaust Muffler Cleaning:

   a. After replacing the pump diaphragms, run the pump for five minutes.

b. Turn the pump off and remove the exhaust mufflers. Soak them for five minutes in a solvent such as alcohol. After soaking thoroughly, dry the mufflers by blowing them out with air flow in the reverse of their normal flow. Replace the filters if there is any indication of clogging.

c. Reassemble the system.

5. Lock Lubrication: Lubricate the key-way on the front access door with Lock Ease, oil or some other lubricant designed for locks.

6. Replacement of Inlet Connector: Inspect the inlet connector for signs of wear and abrasion. Replace the clear plastic tubing if it is worn or if there are any indications of leaks. The inlet tube should slide into the plastic connector with some resistance; if the fit is not tight, replace the connector tube.

MAINTENANCE INSTRUCTIONS - SEMI-ANNUAL MAINTENANCE

1. Impactor Assembly Cleaning:

a. Remove the four screws which attach the impactor assembly to the instrument deck.

b. Disassemble the impactor by removing the four screws which hold the impactor together and pulling it apart, as shown in Figure 26.

c. Thoroughly and gently clean all surfaces of the impactor and seals with an ethyl alcohol dampened cloth or lint-free paper towel.

d. Gently wipe the silicon rubber seals of the lower portion of the filter seal mechanism which remains on the main deck assembly after the impactor has been removed with an alcohol-dampened towel or cloth.

Figure 26. Virtual Impactor Disassembled for Cleaning

e. Reassemble the impactor, making sure that the red rubber gasket is properly in place, before tightening the screws. At all times be careful never to place the silicon rubber filter seals on any surface where they may be damaged or soiled.

NOTE: Unusually heavy filter loadings resulting in values greater than 100 $\mu g/m^3$ will necessitate a more frequent schedule (e.g., every 45 days).

2. Inlet Tube and Fractionating Inlet Cleaning:

a. Remove the inlet assembly from the sampler where it attaches to the inlet tube clear plastic connector.

b. Disassemble the fractionating inlet and throughly wash it with a mild detergent.

c. Thoroughly dry the inlet with a lint free cloth and reassemble the unit.

SECTION 9

TROUBLESHOOTING

Suggestions for troubleshooting are included with the checkout and calibration instructions in Section 5 of this report. For additional troubleshooting instructions, the operator should refer to the manufacturer's Operating and Service Instructions (2). Problems beyond the scope of those instructions should be referred directly to the manufacturer.

REFERENCE LIST

1. Adapted from K.T. Whitby and B. Cantrell, "Atmospheric Aerosols - Characteristics and Measurements," in International Conference on Environmental Sensing and Assessment, Las Vegas, NV, September 14-17, 1975, Institute of Electrical and Electronics Engineers, New York, 1976.

2. "Automated Dichotomous Particulate Sampling System: Operating and Service Instructions," Beckman Instruments, Inc., February 1979.

3. Olin, John G., "A New Virtual Impactor (Dichotomous Sampler) for Fine Particle Air Quality Monitoring," presented at the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 1978.

4. Loo, B.W., Adachi, R.S., Cork, C.P., Goulding, F.S., Jaklevic, J.M., Landis, D.A., and Searles, W.L. "A Second Generation Dichotomous Sampler for Large Scale Monitoring of Airborne Particulate Matter." Lawrence Berkeley Laboratory Report LBL - 8725, Berkeley, CA, January 1979.

5. "Ambient Air Quality Monitoring, Data Reporting, and Surveillance Provisions," U.S. Environmental Protection Agency, Federal Register, 44:27557, May 10, 1979.

6. Ludwig, F.L. Kealoha, J.H.S., and Shelar, E., "Selecting Sites for Monitoring Total Suspended Particulates," EPA Publication No. EPA-45012-118, June 1977.

APPENDIX I

PARTS AND ACCESSORIES

OPERATING ACCESSORIES

1. Vacuum Gauge:

   1 ea. #V500 ¼" LM #47103
   30" Hg Vacuum Gauge with Screw Check

   Available from: Boston Cooper
   Salem Industrial Park
   Manor Parkway
   Salem, New Hampshire 03079
   Tel: (603)893-9181

2. Pump Muffler:

   2 ea #4450 KI 1/8" Pipe Thread
   Combination muffler/filter

   Available from: McMaster Carr Supply Co.
   Post Office Box 4355
   Chicago, IL 60680
   Tel: (312) 833-0300

3. Inlet Connector:

   3 feet #PV2620-1 1¼" Nominal ID x 3/16" wall
   Par Fex Clear Plastic Tubing

Available from: Green Rubber Company
160 Second Street
Cambridge, MA 02142
Tel: (617) 547-7658

4. Standpipe Extension:

As mentioned in Section 4, installation of the Sampler indoors requires an extension to the inlet standpipe and a supporting sleeve. Since the length and material for these accessories will depend on the location and type of sampling required, specifications are not provided here. The standpipe extension should be of 1¼" nominal outside diameter pipe with a 1" nominal inner diameter. Depending on the material selected, pipe and tubing for this purpose should be readily available locally at heating or plumbing suppliers.

CALIBRATION ACCESSORIES

1. Singer Dry Test Meter:

1 ea. Dry Test Meter Model #DTM-115-3 with Dial Temperature and Pressure Gauge

Available from: American Meter Division
13500 Philmont Avenue
Philadelphia, PA 19116

2. Rotameter Assembly (604):

1 ea. Model #7630H Rotameter with 604 Tube
1 ea. Model #7966 Bench Stand
1 ea. ¼" diameter Tantalum Float for 604 Tube

Available from: Matheson Gas Co.
Post Office Box 1147
61 Grove Street
Gloucester, MA 01930
Tel: (617) 283-7700

3. Rotameter Assembley (603):

1 ea Model #7630H Rotameter with 603 Tube

1 ea. Model #7966 Bench Stand

Available from: Matheson Gas Co.
(See address above)

4. Inlet Filter for 603 and 604 Rotameters:

2 ea. #4450 K1 1/8" Pipe Thread
Combination muffler/filter

Available from: McMaster-Carr Company
Post Office Box 4355
Chicago, IL 60680
Tel: (312) 833-0300

5. Inlet Adaptor Assembly (Instructions are given after the specifications):

6 feet ¼" ID x ¼" wall Latex Vacuum Tubing

Available from: Irving B. Moore
30 Rindge Avenue
Cambridge, MA 02139
Tel: (717) 491-0100

1 ea.	#B-4-FHC-2T	Tapered Female Connector
2 ea.	#B-600-7-4	Female Connector
3 ea.	#B-4-MHC-6T	Tapered Male Connector
1 ea.	#B-4-HN	Hex Nipple
1 ea.	#B-IRF4-A	Regulating Valve

Available from: Cambridge Valve and Fitting
50 Manning Road
Billerica, MA 01824
Tel: (617) 272-8270

2 feet Schedule 80, 1" Nominal Diameter Type 1 PVC Pipe

2 ea. Schedule 80, 1" Nominal Diameter Socket Caps

1 pint "80" PVC Cement

Available from: Utility Supply Corporation
425 Riverside Avenue
Medford, MA
Tel: (617) 395-9023

INSTRUCTIONS FOR ASSEMBLY OF INLET CALIBRATION ADAPTOR FOR USE WITH ROTAMETERS

The assembly is shown in Figure 15.

1. With PVC cement, attach a 20-inch length of Schedule 80 1" nominal diameter pipe to a 1" nominal diameter socket cap which has been drilled and tapped to ¼" NPT. Remove all burrs from the open end and use the second 1" cap as a dust cap (do not glue it on).

2. Attach the brass regulating valve's outlet to a ¼" NPT hex nipple.

3. Attach the valve and hex nipple to the socket cap on the tube assembly (do not overtighten the brass to PVC connection).

4. Attach a ¼" NPT tapered male connector to the inlet of the brass regulating valve.

5. Use Teflon tape on all pipe connections.

6. Attach the adaptor assembly to the 604 or 603 rotameter using ¼" ID and ¼" wall latex vacuum tubing.

APPENDIX II

CORRECTION OF ROTAMETER READINGS TO ACTUAL PRESSURE AND TEMPERATURE

The flowmeters described in this manual are manufactured by Matheson. They come with the manufacturer's calibration for air at 70°F (21.1°C) and at atmospheric pressure. We recommend recalibration of all flow measurement devices to a traceable reference standard. The procedure described below is required to convert the calibrated flow readings to actual conditions.

When calibrated rotameters are used at another pressure or at another temperature from the calibration conditions, it is necessary to adjust flow readings for these changes. Departures from calibration conditions result in a change in drag forces on the float ball. These changes are due primarily to changes in density (pressure and/or temperature affected) and changes in air viscosity. Actual flow (operating conditions) is the product of the reading for air times the density factor times the change of flow due to viscosity differences.

$$\text{ACTUAL FLOW} = \text{FLOW READING} \times \text{DENSITY FACTOR} \times \frac{\text{\% OF FLOW CHANGE DUE TO VISC.}}{100}$$

DENSITY FACTOR (DF)

$$DF = \left[\frac{T_1}{T_2} \times \frac{P_2}{P_1} \right]^{\frac{1}{2}}$$

T_1 = 294.3°K (273.2 + 21.1°C) or calibration temperature

T_2 = Operating Temperature (°K)

P_1 = Standard atmospheric pressure (14.7 psia) or calibration pressure may be expressed in any units of pressure

P_2 = Actual atmospheric pressure

VISCOSITY FACTOR (VF)

The viscosity factor is calculated by dividing the dynamic viscosity in centipoise of air at operating conditions by the density of air at atmospheric pressure. The viscosity of air is independent of pressure for the normal range of surface pressures. The viscosity of air is a function of temperature as shown in Figure A-1 where temperature is in degree centigrade and viscosity is in units of centipoise.

Viscosity is divided by density of air at atmospheric presure (1.2×10^{-3} grams per cubic centimeter). The simplified formula for the viscosity factor includes these terms times a pressure and temperature correction term.

$$VF = 833 \text{ (Viscosity)}/DF$$

Figure A-2 is then used to determine the percent of flow calculated. This is determined by following the viscosity factor calculated across to the "float curve" and then up to the horizontal axis to determine the correction factor.

Sample Calculations

Air Temperature: -10°C (14° F) or 263.2 °K

Pressure: 850 mb, 637.5 mm Hg, or 29" Hg

Density Factor: $[(294.3/263.2) \times (29.0/29.92)]^{\frac{1}{2}} = 1.04$

Viscosity Factor: $833 \times 0.01657/1.04 = 13.04$

On Figure A-2 using a glass float gives a percentage correction of 104%

ACTUAL FLOW = Reading x 1.04 x 1.04
= Reading x 1.08
or approximately +8%

Sample Calculation

Calibration temperature T_1 = 25°C (77°F) (298.2°K)
Actual temperature T_2 = 0°C (32°F) (273.2°K)
Calibration pressure P_1 = 790 mm Hg (31.1 inches Hg)
Actual pressure P_2 = 650 mm Hg (25.59 inches Hg)

Density Factor = $[(298.2°K/273.2°K) \times (650\ mm/790mm)]^{\frac{1}{2}} = 0.95$

Viscosity Factor = (833 x 0.01709)/0.95 = 15

From Figure A-2 the correction factor is essentially 100% of flow (or no change due to viscosity differences).

ACTUAL FLOW = Reading x .95 x 1.00

or approximately a -5%

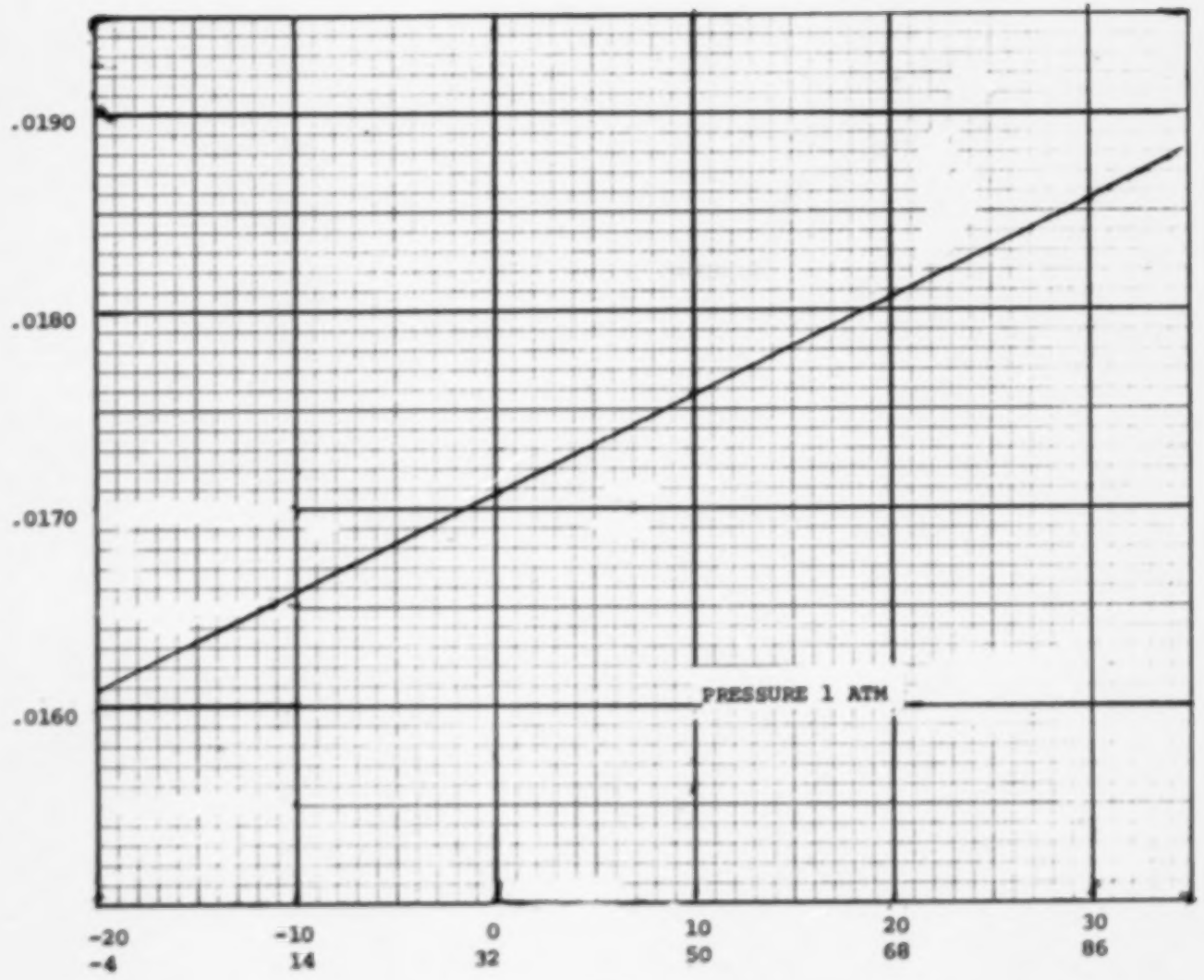

Figure A-1 (Centipoise) of air as a function of temperature ($^{o}C/^{o}F$)

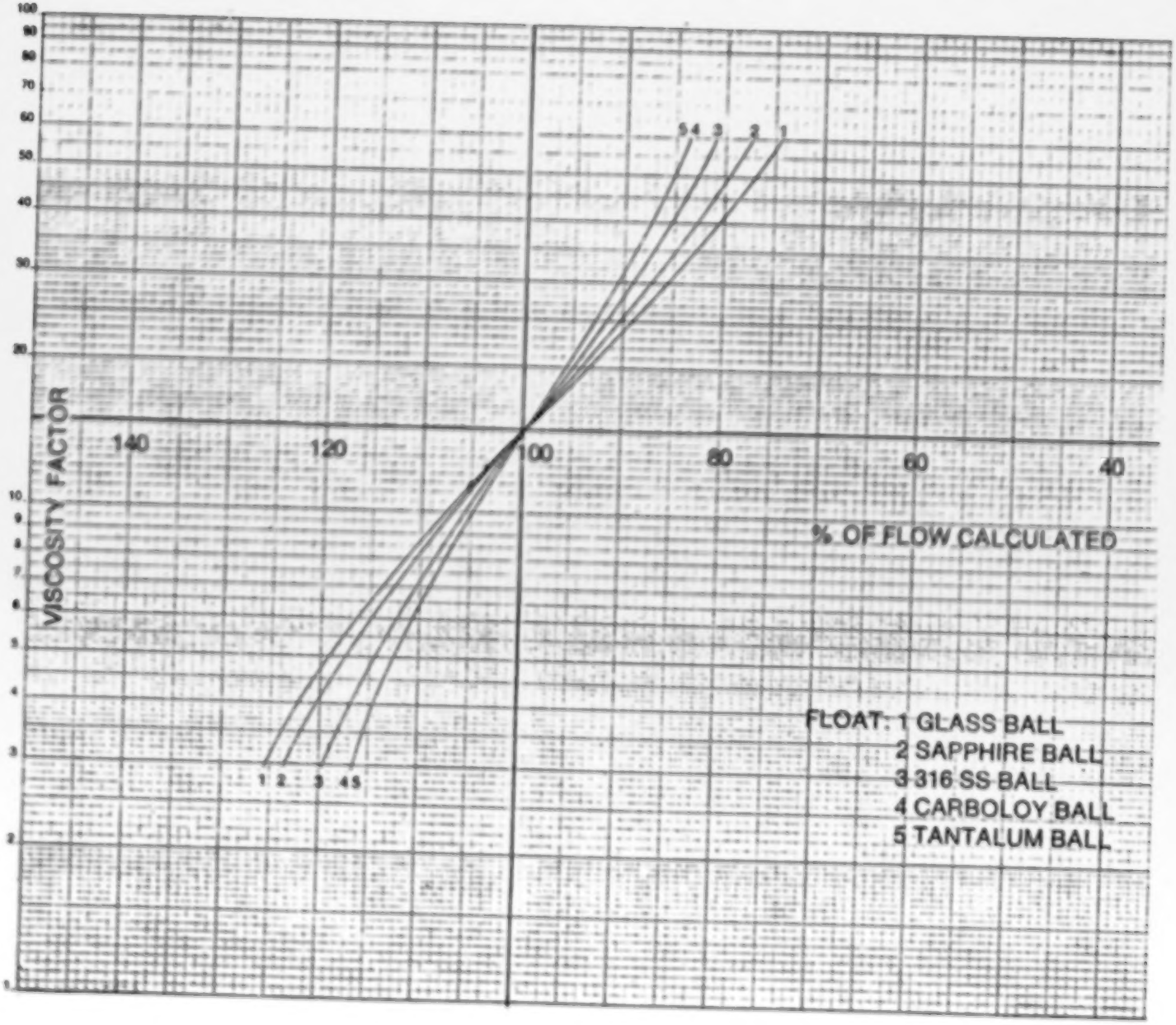

Figure A-2 Percent of flow correction factor for viscosity changes (Matheson 604 Rotameter)